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The color plates for the front cover were kindly loaned by the Kaiser Co., Inc., and show the teeming of steel at Kaiser's Fontana, Calif. plant.

Improving the Impact Stress Endurance of a Carburized Gun-Part

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A hammer for an automatic gun was giving service failures from fatigue after about 5000 rounds. It was desired to increase this life several fold, and to investigate the suitability of a low alloy NE steel for the S.A.E. steel originally specified. Tests are outlined showing how heat treatment, shot peening, and surface protection affected the endurance of the part.

An automatic-gun hammer, which in operation was subjected to impact at the approximate rate of 450 cycles per min., was originally manufactured from S.A.E.4620 steel, carburized to a total case depth of 0.025 to 0.030 in., quenched directly from the carburizing heat into oil, and tempered to hardness Rockwell C-56 to 59. Hammers made to this specification had an average service life of 5000 cycles; typical failures are shown in Fig. 1. An investigation was undertaken to study the effect of various types of steels and treatments on the endurance of this part and the results of this investigation are herewith presented.

Testing Machine — In order to test some of the factors affecting the endurance of this part, a machine was built which simulated operating conditions. Comparison of test results with reports of parts that failed in actual service established that this test machine closely duplicated field conditions, since it caused the same type of failures in about the same cycles. This machine is shown in part in Fig. 2. The hammer and striker pin were assembled in a breech block *B* which was held rigidly against the frame of the machine by set screw and shims. Only the protruding lugs on the hammer can be seen at the left of the breech block. The hammer plate *P*

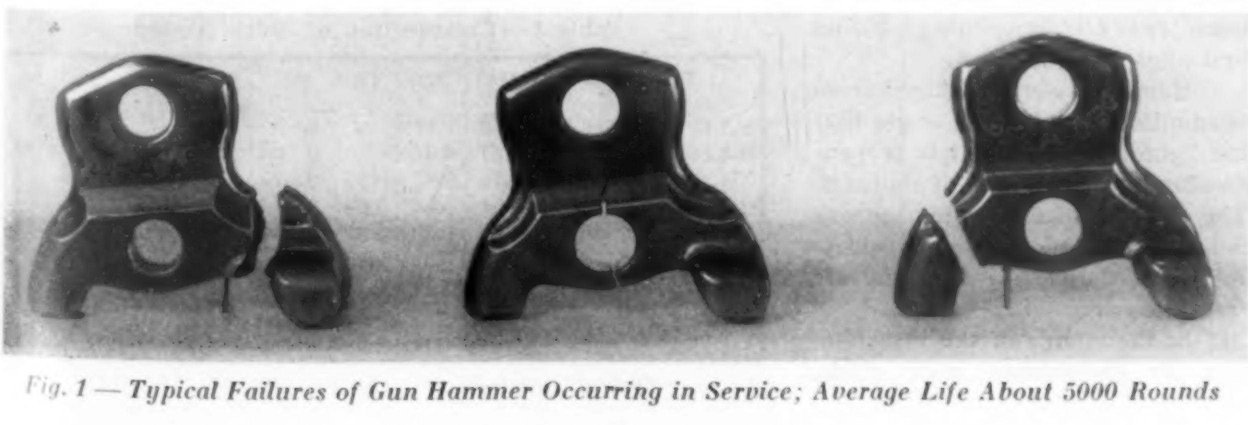


Fig. 1 — Typical Failures of Gun Hammer Occurring in Service; Average Life About 5000 Rounds

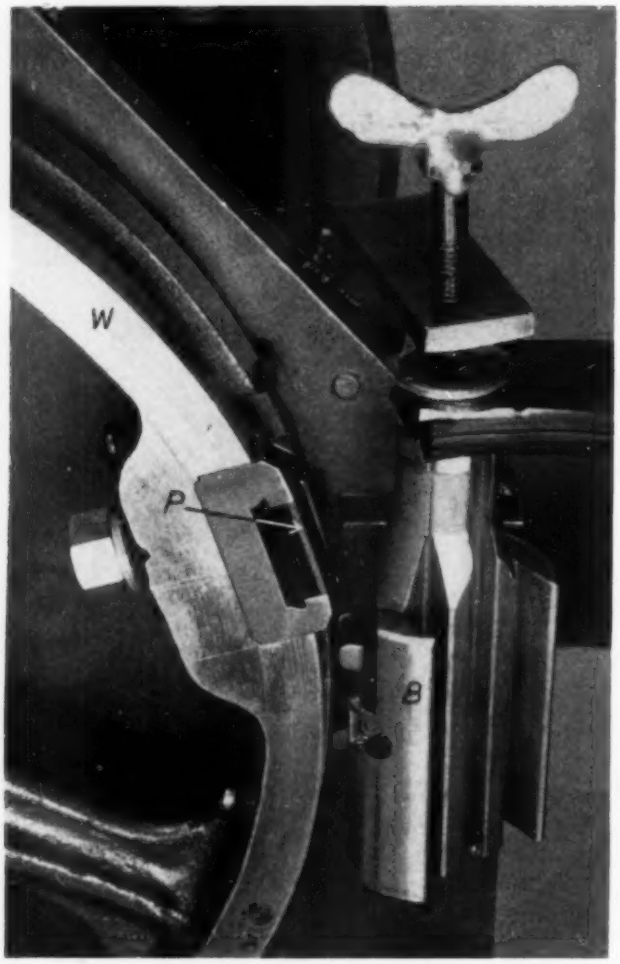


Fig. 2 — Testing Machine in Position Where Hammer Plate P Is About to Engage Hammer, the Latter Mounted in Breech Block B

was mounted on the periphery of a wheel *W* and when rotated 450 times per min. struck the hammer with a force equal to the recoil of the gun.

Figure 3 illustrates the relative positions of the hammer plate and hammer during the operating cycle.

Tests Run and Materials Used — Tests were run to determine the effect on endurance of *(a)* type of steels, *(b)* shot peening, *(c)* salt bath quenching, *(d)* case and core hardness, *(e)* certain plating, bluing and phosphate coatings.

Hammers were machined from normalized forgings, so made that the "grain" of the steel is perpendicular to the plane of failures. The radius at the camming toe was polished, in order to avoid stress raisers at the region where failure frequently started.

In the course of the investigation six carburizing grade steels, one oil hardening steel, and one nitriding steel were used. All steels tested were fine grained. Chemical analyses are listed in Table I.

The carburizing compound used met the following specification: Coke, 25.0 to 30.0%; sodium carbonate, 1.0 to 2.0%; calcium carbonate, 3.0 to 5.0%; barium carbonate, 10.0 to 15.0%; Moisture, 1.0% max.; hardwood charcoal and binder, balance; sulphur, 0.25% max.; foreign matter, 6.0% max. A mixture of about one-quarter new compound and three-quarters old compound was used in each run.

Evaluation of Steel Types

The first series of tests with this impact machine evaluated the endurance of parts made from steels S.A.E. 4620, NE8620, NE9420, NE94T22, G.M. X-9115, S.A.E. 4340 and Aero Special No. 6470. The heat treatments used and the cycles to failure are listed in Table II. It rapidly became evident that these parts were operated at stresses exceeding their endurance limit. It was also evident that the resistance to failure of the mild alloy steels NE8620, NE9420, G.M. X-9115 and NE94T22 is considerably lower than that of the higher alloy S.A.E. 4620, the standard steel for this part. (In this series of tests this steel did a little better on the average — 9000 — from the service records, e.g., 5000.)

Other observations on the results of tests in Table II are as follows:

On Steel NE8620 a single quench direct from the pot gave better results than pot quenching followed by reheating and quenching from 1400° or 1425° F. Note the large difference in test results caused by a difference of 25° in the reheating temperature of treatments B and C.

NE9420 and the grainal treated NE94T22 steels showed about the same tendency to failure.

Due to the difficulty of flame hardening the toes only on hammers made of oil hardened S.A.E.4340, the use of this steel was considered impractical, although it had about the same

Table I — Composition of Steels Tested

Type	C	Mn	Ni	Cr	Mo	Si	P	S	Al
S.A.E. 4620	0.20	0.56	1.79	—	0.27				
S.A.E. 4621	0.21	0.87	1.96	—	0.21				
NE8620	0.20	0.79	0.67	0.56	0.25				
G.M. X-9115	0.17	0.64	—	0.64	0.17	0.90	0.020	0.021	
NE9420	0.22	0.90	0.29	0.35	0.10	0.48	0.032	0.028	
NE94T22 *(a)*	0.23	1.05	0.39	0.28	0.10	0.53	0.028	0.020	
S.A.E. 4340	0.40	0.71	1.78	0.75	0.26				
Aero Special No. 6470	0.42	0.67	—	1.48	0.36	0.29	0.015	0.033	0.80

(a) "Grainal" treated.

endurance as the standard part. Furthermore it contains more alloy.

Low results obtained with the nitriding steel (Aero Special No. 6470) indicated that it offered no advantages in this particular application to an automatic-gun hammer.

Fig. 3 — Relative Location of Hammer and Hammer Plate at Three Stages of a Single Cycle of Operation

Condition of Case

A comparison was made of the carbon concentration in the carburized surface layers of NE8620 and S.A.E. 4620 steels to determine whether this could account for the large difference in performance of two steels whose case depth and hardness (both case and core) was so closely similar.

Bars 2 in. in diameter were machined smooth from both steels and carburized at 1600°, 1650°, and 1700° F., respectively. Increments of the case were turned off and the carbon content determined. Very little difference was found in the carbon content of the surface layer of these two steels, when carburized in solid compound at these temperatures. Curves of carbon content plotted against distance from the surface are given in Fig. 4, page 470.

These results indicate that the difference in the life of parts made from these steels was not due to a difference in the carbon concentration at the surface — or at least in the average content of the first 2½ thousandths.

Effect of Shot Peening

Tests run to determine this effect encountered difficulty in obtaining suitable operational technique. The size of shot, the velocity, intensity, and angle of impingement are important factors, and must be carefully controlled. Eventually chilled iron shot, 0.023 to 0.033 in. in diameter, were used by us. Four stationary nozzles were set at positions to give the desired angles of impingement at the surfaces to be peened. Air pressure of 100 psi. was maintained on the jet, while the hammer was passed under the nozzles four times.

Table III, on the next page, lists the results obtained from S.A.E. 4620, S.A.E. 4621, NE8620, and NE94T22. These parts were carburized, quenched in oil, and tempered per treatment A of Table II, then shot peened.

A run of 30,000 impact cycles was considered to be a reasonable life for these parts, since at this time the wear of the cam toe became excessive.

Table II — Heat Treatments and Cycles to Failure

Steel	Treatment	Cycles to Failure			Tests	Annealed Case Depth	Hardness	
		High	Low	Average			Case	Core
S.A.E. 4620	A	20,000	5,000	9,000	10	0.027	C-57	C-39
NE8620	A	4,597	3,086	4,196	5	0.026	C-58	C-40
	B	6,842	1,546	3,778	6	0.028	C-57	C-30
	C	1,573	452	850	5	0.027	C-57	C-23
G.M. X-9115	A	4,648	760	2,600	6	0.028	C-57	C-39
NE9420	A	12,182	4,160	8,086	6	0.026	C-57	C-40
NE94T22	A	11,531	1,694	6,643	6	0.028	C-59	C-42
S.A.E. 4340	D	11,112	5,490	8,251	5			C-37
Aero Special No. 6470	E	3,971	1,452	2,537	6	0.018	File hard	

TREATMENTS — A: Carburized at 1650° F., quenched in oil, tempered at 450° F. B: Carburized at 1650° F., quenched in oil, reheated to 1400° F., quenched in oil, tempered at 450° F. C: Same as B except reheated to 1425° F. D: Heated to 1525° F., quenched in oil, tempered to C-37, toes flame hardened. E: Oil-quenched and tempered to Brinell 321, then nitrided.

Table III — Endurance of Shot Peened Parts of Various Surface Hardness

Steel	Tempering Temperature (a)	Hardness	Parts Tested	Unbroken at 30,000	Life of Failed Pieces	
					Min.	Max.
S.A.E. 4620	450° F.		16	16		
NE8620	450° F.		6	4	15,000	21,000
NE94T22	450° F.		7	6	8,000	
S.A.E. 4621	450° F.	C-58	10	10		
	700° F.	C-47	5	1	19,933	30,000
	875° F.	C-43	5	None	10,201	12,218
	1050° F.	C-37	5	None	6,115	12,195

(a) Prior treatment of all parts was to carburize and quench in oil. Shot peening was done after tempering.

By comparing the data listed in Table III with that presented for the same steels in Table II, it is apparent that shot peening increased the endurance of this part to a very considerable degree. (Parts made of S.A.E. 4621 steel were available at this time and consequently were included in this test.) Again it will be noted that the higher alloy steel parts (S.A.E. 4620 and 4621) had a better record of performance than the lower alloy (NE8620 and NE94T22).

Effect of Hardness

Tests were also run to determine the effect of lower hardness on the endurance of this part. Because of excessive peening during normal action between hammer and hammer plate the proper cam angle could not be maintained on the testing machine without a similar decrease in the hardness of the hammer plate. Therefore, the hammer plates used in this series of tests were 2 to 4 points softer on the Rockwell C scale than the hammers being tested. These plates were changed frequently to maintain the proper cam angle at all times.

Parts made of S.A.E. 4621 steel carburized, quenched in oil, tempered at 450° F., then shot peened were employed as a reference standard. The softer parts were tempered prior to shot peening. Results of these tests are listed in the last three lines of Table III, and show that any drop in hardness below C-58 will be accompanied by a loss of endurance.

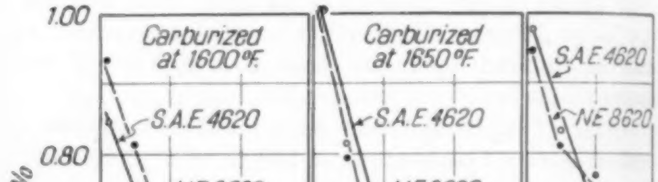


Fig. 4 — Carbon-Penetration Curves for 4620 and 8620, Carburized at 1600, 1650 and 1700° F.

Effect of Salt Bath Quenching

Because of the improvement obtained on shot peening these hammers of S.A.E. steels when oil quenched, tests on salt bath quenching were limited to parts made of NE8620 steel. It was believed that salt bath quenching would decrease the intensity of surface tensile stresses, since such a heat treatment results in a slower rate of austenite transformation than when the same steel is quenched in oil.

Two problems presented themselves — first, to determine the correct length of time to hold the part in the salt bath; second, to determine the correct temperature of the salt bath. The degree of brittleness was considered a criterion for determining the *time* factor; as quenched (or quenched and then held for short

Table IV — Tests on Carburized NE8620 Gun Hammers Quenched in Salt Bath and Held 2 Hr.

Temperature Salt Bath	Shot Peened	Parts Tested	Hardness		Not Broken (a)	Life of Failed Pieces		
			Case	Core		Min.	Max.	Average
450° F.	No	4	C-58	C-39	None	5,185	13,039	8,577
450° F.	Yes	3	C-58	C-39	1	19,929	22,183	
450° F.	Yes	29	C-60	C-40	12	535		10,547
450° F.	Yes	8	C-60	C-40	2	571		3,103
450° F.	Yes	17	C-60	C-40	None	700		6,206
450° F.	Yes	15	C-60	C-40	7	560		13,338
480° F.	Yes	15	C-59	C-40	14	24,000		
500° F.	Yes	16	C-59	C-40	13	11,000	12,000	

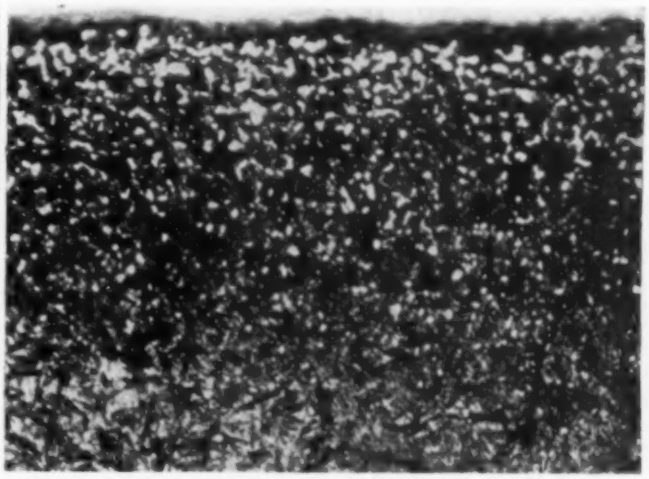
(a) No incipient cracks after 30,000 cycles

time intervals) the parts were exceptionally brittle. A holding time of about 2 hr. in the bath was found necessary to eliminate this severe brittleness. Second, as to *temperature*: Inasmuch as these parts had previously been tempered at 450° F. in routine manufacture, a salt bath at this temperature was tried. The salt bath used was about half potassium nitrate and half sodium nitrite.

Parts were therefore carburized and quenched into salt at 450° F. The resultant hardness was Rockwell C-58 to 60. Preliminary tests on such parts indicated that they had an improved endurance over those heated in the "standard" manner. The results of these preliminary tests are listed in the first two lines of Table IV. These data also indicate clearly that shot peening increased the endurance of the parts so treated.

Fig. 5 — Undesirable Brittle and Acicular Structure; Quenched in Salt at 450° F. and Held 2 Hr.

Fig. 6 — Desirable Carbides (Spheroidized) After Quenching in Salt at 480° F. and Holding 2 Hr.



Microstructures at 500 Diameters of Carburized NE8620 Gun Hammers (Nital Etched)

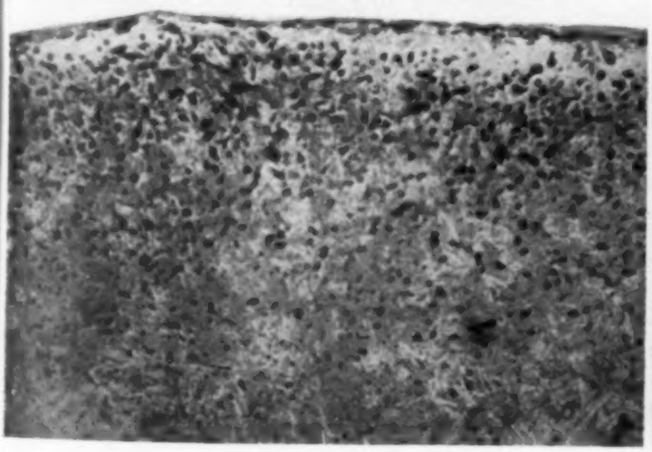


Fig. 7 — Same as Fig. 6 Except Etched With Alkaline Sodium Picrate

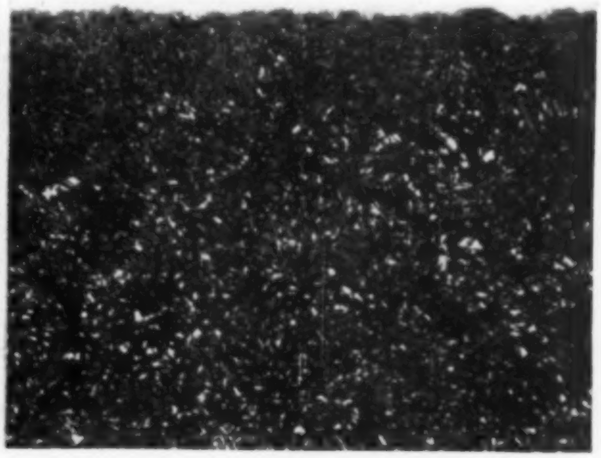
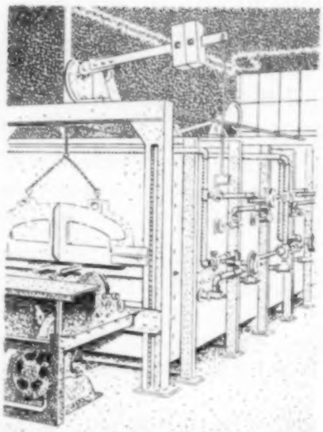


Fig. 8 — Tempered Martensite Resulting From Oil Quench and 450° Draw

It was felt that these results were sufficiently satisfactory to warrant further investigation of salt bath quenching followed by shot peening. Accordingly, tests were run on a larger number of parts to obtain additional information relative to this treatment. The results of these tests were very erratic and confusing, as shown by the data listed in lines 3 to 6 inclusive.

Microexamination revealed one interesting factor: The parts that failed at a low number of cycles contained areas of a mixed acicular structure at the surface, such as shown in Fig. V. (This is believed to be an undesirable structure to have at the surface of a part that operates under repeated impact stresses.) On the other hand, parts that did not fail at 30,000 cycles possessed a small amount of spheroidal carbides at the surface. Therefore it appeared that 450° F. was at or near a "critical" quenching bath

temperature for this material, and the salt bath was heated a little hotter in an effort to eliminate this acicular structure at the surface. Accordingly, parts were carburized, quenched in salt at 480° and 500° F. respectively and shot peened. The results obtained from these tests are listed in the last two lines of Table IV, page 470.



It would appear that a marked increase in endurance was obtained by quenching in a salt bath somewhat above 450° F. Microexamination of parts so quenched revealed no acicular structure; spheroidal carbides predominated in the surface areas as shown in Fig. 6 and 7. (For comparison purposes a photomicrograph of the surface area of a part made from the same NE8620 steel carburized, oil quenched and tempered at 450° F. in the conventional manner, is shown in Fig. 8.)

These tests clearly demonstrate that salt bath quenching followed by shot peening increase the endurance of this part when made from NE8620 steel. However, it must be noted that the temperature of the quenching bath is critical to the extent that if too low (450° F.) many low-cycle failures occur from a brittle structure, and that the best results are obtained at or near 480° F.

Effect of Surface Coatings — Tests were also run to determine the effect of chromium plating, cadmium plating, tin plating, lead plating, phosphate coating and "bluing" on the endurance of this gun hammer.

It will be recalled that tests shown in Table III determined that S.A.E. 4621 steel parts (carburized, quenched in oil, tempered at 450° F., and then shot peened) endured 30,000 cycles of operation without failure. Therefore parts of this steel, so heated, were used for tests on surface treatments. The plating was done in accordance with recognized practices and was applied to the parts after shot peening. The thickness of plating was between 0.0005 and 0.001 in. After plating, the parts were heated to remove occluded hydrogen.

The phosphate coating was also applied in accordance with recommended procedure. Parts were held in the phosphate bath 45 min. Tests were run on parts that were subsequently baked, and on parts that were not heated after surface treatment.

"Bluing" was accomplished in a convective air furnace at 450° F.

Table V, listing the data obtained from this series of tests, indicates that chromium plating, tin plating, lead plating, cadmium plating, and "bluing" decreased the endurance. On the other hand, the phosphate coating apparently had no detrimental effect on endurance, but this coating did not adhere exceptionally well to the steel base. Consequently relatively large areas flaked off under the repeated deflections.

Conclusions

From these tests the following conclusions can fairly be drawn:

1. The endurance of this part, when made from NE8620, NE9420, NE94T22 or G.M. X-9115 carburized, quenched in oil, and tempered, was lower than the endurance of the part when made from S.A.E. 4620 steel and treated in a similar manner.

2. Suitable substitution of NE8620 for S.A.E. 4620 for this part could be accomplished by the use of closely controlled salt bath quenching followed by shot peening.

3. Shot peening resulted in a decided increase in the endurance of this part.

4. A decrease in the hardness of this part was accompanied by a loss of endurance.

5. Chromium plating, cadmium plating, tin plating, lead plating and bluing at 450° F. decreased the endurance.

6. Phosphate coating had no apparent effect on the endurance of this part.

Table V — Effect of Surface Coating on S.A.E. 4621 Gun Hammers, Carburized and Shot Peened

Surface Treatment	Baked 3 Hr. at	Parts Tested	Unbroken at 30,000	Life of Failed Pieces	
				Min.	Max.
Peened only	—	10	10		
Chromium plated	375° F.	6	1	6,438	21,168
Cadmium plated	350° F.	5	1	11,066	21,090
	475° F.	5	1	5,695	22,890
Tin plated	375° F.	5	2	14,732	27,228
Lead plated	350° F.	6	3	7,802	20,252
Phosphate coated	Not baked	9	7	18,978	23,000
	375° F.	9	8	24,842	
Blued at 450° F.	Not baked	15	3	4,024	28,602

Metal Sponges

(articles with controlled porosity)

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The author emphasizes that whereas porosity is an inherent property of powder compacts, and reduced or eliminated only by expensive operations, controlled porosity and permeability are the prime object of the producer's art. These factors are very adversely affected by such operations as reaming, boring, turning or grinding, all of which can usually be avoided if the purchaser will make known his true requirements in advance.

ALL commercial objects made from metal powders may be spoken of as being "metal sponges", for in the forming of compacts it is unavoidable that a considerable portion of voids remain between the individual particles. They are due to trapped air and due to the resistance of the particles of the material to deformation.

During heat treating of the compacts these voids undergo certain changes in shape and size which change the ratio of porosity. The task of eliminating these voids — this inherent porosity — as much as possible, requires prolonged heat treatment and subsequent operations such as re-pressing, or forging, sometimes at elevated temperatures, often followed by additional heat treatment.

A dense material is required for metallic tungsten products, carbide cutting tools, magnets and seal rings. Other parts produced from metal powders have to have the strength and other characteristics of competing materials such as castings and forgings. In every instance the reduction of unwanted porosity adds to the cost.

There are, on the other hand, applications where porosity is very desirable and where it gives to products of powder metallurgy an advantage which is undisputed by competition of other materials.

Wherever friction has to be met between moving parts, as in bearings and in gears, a porous metal structure filled with suitable lubricants gives an ideal condition for maintaining an oil film, the latter for reducing friction and preventing seizure of mating surfaces. It is interesting that even without the intervening oil film seizure does not occur in porous structures due to the spongy nature which seems to prevent adjoining metal particles from welding together.

In the finished bearing or gear the porous structure consists of a very smooth surface with no projection above but innumerable pores and depressions below the contacting bearing surface.

Much has been said in recent years about "Superfinish", the method of measuring it and its effect on friction. An economical mirror finish for shafts and bearings has been the dream of engineers. It can readily be obtained by finishing methods which take advantage of the compressibility of the sintered porous metal compact.

The level surface of the oil retaining material, with its numerous depressions *below* the surface, should satisfy the proponents of superfinish and at the same time reconcile the bearing lubrication experts who insist on rubbing surfaces to which the oil can cling. The superfinish topographer should bear in mind, however, that in measuring surface irregularities he should look for the hills above the plains, and give due credit for the valleys and pot holes which a thoughtful technologist provided below the surface for maintaining and supplying an oil film.

Hardness testing of porous metal structures is a similar case in which a more logical use of testing procedure and interpretation of test results is recommended. Hardness figures obtained by crushing a comparatively large area will not do justice to the particle hardness of a porous metallic structure. A carborundum wheel under the same conditions will not show the hardness of massive carborundum. A hardened porous iron may show the indications of file hardness, but hardness figures obtained on standard indentation testing machines would condemn the material on the basis of a comparison with solid steel articles.

In other words, specifications should be drawn with due regard for the usefulness of a material for a definite purpose and should not necessarily be repetitions of restrictions which may have been justified in the past when available materials were more limited.

To mention the smooth finish of the bore in this new type of bearing would not be justified if these bearings did not retain this condition after installation. Correct bore size and alignment are obtained by methods which make reaming unnecessary. These methods are confined to the porous bearing and are possible because of its compressibility during installation.

The spongy structure of porous bearing metal further permits the storage of a considerable amount of lubricating oil which, through capillarity, is brought to the surface as required. It maintains lubrication between shaft and bearing even after part of the original amount of lubricant has been lost. The same force which prevents a sponge of organic matter from becoming partly dry in one section while remaining wet in others also maintains, in the metallic sponge of the bearing, a uniform and balanced condition of liquid lubricant.

Oil brought in contact with any part of this metal structure is readily absorbed. Additional lubrication can be provided by surrounding the bearing with an oil well. Since the same force which causes absorption of oil also retains it in the structure, a small amount of oil goes a remarkably long way. In many instances no additional lubrication is required during the useful life of the machine. This is not so strange because dust is also kept out of the oil by close fits, by the filtering of additional oil through the spongy wall, and by eliminating oil holes and oil grooves. The latter are unnecessary and the expense and inconvenience resulting from their use in conventional bearings is eliminated.

Noise reduction in bearings and gears made of oil-filled porous metal is quite noticeable.

In order to provide a most suitable structure which takes full advantage of the natural characteristics of heat treated metal powder sponges for oil retaining porous bearings it is necessary to develop intercommunicating porosity at its best and to provide oil storage to the highest degree compatible with required strength.

Metal powders of proper particle size and particle size distribution in proportions for proper alloying, and with additions of lubricants and void producing ingredients are the basic materials from which the compacts are molded.

Bronze of the 90% copper, 10% tin composition, with or without graphite, is widely used. The graphite acts, for one thing, as a die lubricant. It also produces a very desirable type of porosity and non-seizing characteristics. Porous iron, with and without copper, is also finding favor today — not merely in order to save strategic materials but for its greater strength and suitability for certain applications.

Metal Filters

In the production of some metal filters, these metal powder mixtures are merely poured into a mold without the application of pressure, and the mold and its contents are put through a sintering furnace. Under these conditions a very high and a very uniform porosity is obtained without much effort.

In order to obtain the stronger structures required for bearings and gears, much denser compacts have to be made. They must be rigid enough to allow handling on their way from the briquetting presses to the furnace and as they go through the furnace without lateral support.

In order to maintain uniform density in these compacts, types of tools have to be used which are quite different from the molds or dies for casting, forging, pressure casting, injection molding or for the compacting of plastic material in ceramics and synthetic plastics. The non-plastic characteristics of metal powders have made it necessary to design presses and press tool movements which heretofore had not been required in other industries.

The first compacts made by the manufacturing methods we now call powder metallurgy were of simple shape and had to be finished by machining when parts of more complicated forms were the ultimate object.

The mass production of bushings with thin walls, with flanges, with non-uniform cross sections and steps have been more recent developments. They required new methods of production and created a market for metal powders of

unique characteristics, and also for parts which did not necessarily have to have the spongy structure of the oil retaining porous bearing.

Inherent porosity of metal compacts has been mentioned. This does not mean *uniform* porosity and it does not mean *controlled* porosity. Both of the latter, as they exist in the commercial object, are the result of art and engineering; they are not by any means inherent. The lateral friction during compression and during ejection requires special attention. Compacts which have to be sized after heat treatment must be dimensioned so that neither porosity nor permeability are unduly deranged during the finishing operation. Variations in thickness in the direction of pressing may result in considerable variation of density if not properly taken care of. Sometimes variation in density is not objectionable.

Reaming, boring, turning or grinding affect permeability very adversely. These operations when applied to porous bearings are expensive, generally uncalled for, and reflect therefore upon the purchaser's lack of familiarity with the possibilities of this material.

To sum up — the great demand for controlled porosity of powder metal products, such as bearings, filters and gears, calls for a thorough knowledge of the art of producing metal sponges and for the proper application of lubricants. To this should be added a very liberal acquaintance with product engineering and modern methods of shop practice.

Critical Points

By the Editor

MOTORED out from Pittsburgh to a hilltop near New Kensington, a rural spot miraculously untouched by surrounding coal mines and industry, whereon is placed Gulf Oil Corp.'s research laboratory, grown in 15 years from a single fellowship at Mellon Institute to a spreading group of buildings and a staff of 1100. Shepherded by Blaine Wescott and Clifford Hunter, devoted a day to the metallurgical and chemical work on oils, in their respective charge. Most impressed by the variety of equipment for testing bearings and lubricating oils — a great room full. Hunter says the first thing to do when having bearing trouble is to try to take heat away from it; cool the hot box, as it were. Nearly all things that are potential trouble makers are more dangerous as temperature runs up. For example, the change from unctuous oil to corrosive acid is an oxidation process, enhanced by heat. So — *keep bearings cool!*.... Wescott described some early work, but nevertheless of enduring importance, on corrosion of sucker rods, down deep in oil wells where the liquids have no free oxygen trapped or in solution. Roughly the conclusions are that plain carbon steel is good enough for light loads in "non-corrosive" liquids, but in deeper wells a medium manganese alloy steel is required. To operate in the more corrosive but sulphide-free brines, the S.A.E. chromium, chromium-nickel or low nickel steels are necessary, whereas a modified 4620 (about 0.3% chromium) or 2½% nickel steel is best if the brine contains some H_2S.... Also interested in some unusual equipment for recording cooling curves during quenching. A small pencil of 18-8 or nickel (to avoid scale and internal heat evolutions) has a thermocouple head at its geometric center, and is dropped out of a vertical tube furnace into a quenching bath and the recording apparatus simultaneously tripped. The latter uses a seismograph (modern adaptation of the divining rod, got from the geophysical section) which photographs a time-e.m.f. curve on a film moving rapidly enough to register 1/20-sec. intervals. Quenching curves for water solutions show that the insulating steam first formed around the specimen persists for about 2 sec.; then the water "takes hold" and cooling by steam formation is very fast down to the boiling point. Straight mineral quenching oils do not break through this gas sheath for 12 or 13 sec.; cooling in the second stage is still only about half as fast as in water for oil has a lower heat of vaporization, and the delay is such that transformation of austenite to fine pearlite has already started in all except very sluggish steels. To increase the quenching power

Corrosive oils and brines

Fast oil quenches

of oil, therefore, it was necessary to find some addition agents that cause the vapor sheath to collapse more quickly, in say 5 sec. (so the cooling curve is moved to the left and does not cut the nose of the S-curve). Such agents do not change the shape of the lower part of the cooling curve, below say 700° F., the approximate boiling point of the oil. From here on down cooling is by conduction to liquid bath, and is slow enough so that the temperature throughout the piece has a chance to equalize and also the austenite-to-martensite reactions, with accompanying volume changes, cause a minimum of warpage and residual internal stress — the same thing as cracking tendency. The ideal is the fast quench of water to 700° F. to retain the austenite, and the slow quench of oil below 700° F. to prevent warps and cracks during martensitic formation. Utility of such improved oils is for the jobs requiring quenching rates between still water and agitated oil, where the mass of the part is moderate, the steel has intermediate hardenability, full martensitic hardness is required on the surface and warpage must be minimized. . . . . PRACTICAL NOTE: A very thin furnace scale (bluish color) increases the rapidity of quench over that of a polished sample, since the slightly roughened surface nucleates more vapor bubbles. *Heavy* scale is bad for quenching speed, as everybody knows.

MANY were the stories about hapless Londoners trying to douse incendiaries during the blitz, said incendiaries being magnesium shells ignited by a reacting mixture of aluminum powder and iron oxide (thermit). The thermit reaction is not only unquenchable and unsmotherable, carrying its own oxygen, but produces such overheated steel and corrosive slag that it melts and eats through metal, slate, tile and other "fireproof" roofs and barriers. (American ordnance even has a more destructive variety called thermate, or thermit plus other reagents.) Magnesium, also, once ignited, feeds on water, wood and other oxygen compounds. Our own magnesium program was based on astronomical requirements for 2-lb. and 4-lb. bombs of this sort. It turned out that we got much more magnesium than we need for this purpose; even though two-thirds of the Chemical Warfare Service expenditures are now for incendiaries, we are making other kinds. You might like to know that they are based on "jellied oil" and on white phosphorus. The jellied oil is a modification of Standard Oil Development Co.'s "thickened fuel" — another of those peace-time researches. Fire bombs come in three sizes, the 6-lb. M69 baby, the 100-lb. M47 daddy, and the 500-lb. M76 "goop" or PT bomb. The effective ingredient was originally gasoline mixed with crude latex, caustic soda and coconut oil, but what with the rubber shortage, an even more nasty jello is made of petroleum and a synthetic resin — "gel-gas" in chemical warfare jargon. The light steel casing contains a bursting charge, and the larger bombs also have magnesium granules, so inextinguishable chunks of flaming gel and metal are scattered over a whole block. White phosphorus is put up in a cigar-shaped package about 3 ft. long (the M1 30-lb. bomb) and its dense white smoke is hard to live with even though you escape being burned by the sticky stringers that scatter about. All these varieties have appropriate fuse mechanisms, which explode them either above the target, on contact, or after penetration. For accurate marksmanship from reasonably high altitude, large bombs are necessary, so the little ones are tied into 500-lb. clusters with timing devices that scatter them when reaching a certain altitude. A few canisters of TNT, with delayed action fuses, discourage the fire fighters on the receiving end. . . . . Adolph, you asked for it.

Gel-gas for fire bombs

REMINISCING with Dewey Hult, happily met in a Pullman, about stunts devised in the dead depression days to keep plant, body and soul together, and he told of two items that may be of more than personal interest. His firm, the Auto Engine Works of St. Paul, was able to pick up some useful replacement business in gas engine heads. First a change in design from flat to a shallow dome brought marked stiffness, and this was enhanced by casting them in alloy iron with modulus nearly double that of the usual gray iron. The real gain was in valve life; smaller head deflections meant better seating, not only avoiding blow-by but also transferring more heat from valve to the cooler head. . . . . Another bread-and-butter job was the unconventional one of reclaiming worn diesel engine shafts. Crank pins and main journals would be machined or ground well undersize, then grooved. Tops of the remaining ridges would then be knurled, roughening their surface but also upsetting them sideways. Next music wire was fed into a metal spray gun and the grooves filled and the whole bearing built oversize, ready for grinding. Shock cooling of the metal spray gave a very hard surface, and the rough tapered grooves lent mechanical anchorage. Good as new — better than many of them had ever been, in fact, says Hult.

Rebuilding worn journals

ABOUT a year ago *Metal Progress* published a short list of metallurgical problems posed by the War Department, problems whose solution would expedite the war effort, and invited metallurgists, inventors, and just plain citizens to send their thoughts to the National Inventors Council. This brought at least one response, in Rolf Gall's column "Personalities — Plus" in the Chicago *Daily News*:

Information, please

Higgledy, Piggledy

The editor of *Metal Progress* says that a simple process is urgently needed by the war industries for darkening aluminum. We have such a process right in our own little kitchen. But we dood it without knowing how we dood it.

This, and the other problems of that time, may have been solved in a practical way, for the latest list received from the War Department of things for inventors to worry about relates to explosives, incendiaries, and less lethal chemical compounds, and contains little or nothing of a strictly metallurgical nature. A portable grinder (250-lb. weight) for sharpening detachable rock drill bits is needed. Likewise, if anyone has photographs or any technical data about enemy plants — particularly in out-of-the-way places — notify the War Department immediately.

SOME MONTHS AGO the Associated Press sent a badly garbled wire out of Los Angeles about an alloy steel "600 times tougher than nickel alloy and 150 times tougher than chromium alloy. Research by the Kaiser Steel Co.," the dispatch continued, "proved that unexplained cracks in newly rolled steel sheets were due to the presence of boron, an alloying element added by mistake; and when the boron was reduced, flawless, extremely tough steel emerged from the rollers." This startling announcement caught the eye of many newspaper editors not familiar with the grandiloquent phraseology of the reporters in the great wide open spaces, and it was widely reprinted. Three ⊕ friends sent it in with various comment, best suppressed. Another sent a paraphrase of an old sing-song:

Read 'em and weep

Oh you put the boron in
Or you take the boron out
But the steel is always better
Just the same!

GRATIFIED to hear that a pot-boiler written during the early days of *Metal Progress* helped solve a critical problem in war production on the opposite side of the world. This news was learned from Arthur Reardon, Australian ASMember, here last winter to observe forging and heat treating methods for the Commonwealth's Ministry of Munitions. (If Australians of the other sex are as vivacious and friendly as he, no wonder so many American soldiers are marrying over there!) His story is this: In the dark days when the Japs were furthest south, threatening Port Moresby just across the straits in New Guinea, the Australian production of indispensable field guns was just about stopped by failures of the firing pin spring. This spring fits closely over a ¾-in. spindle and operates within a 1⅛-in. bore in the breech block; thus the size of the spring wire could not be increased and fit into existing guns without changing the size or design of one or two other essential parts. When made of round spring wire and heat treated in a conventional way, the springs could not meet a trick "impact test" of 25 ft-lb. minimum. By careful adjustment of hardening and tempering conditions, a fair proportion of these springs would withstand 24 ft-lb., and in view of the emergency, these were put into assembly. However, they lost a little in free height after passing through several working cycles. Fatal, however, were the numerous failures occurring after a few days in the breech assembly, where the "uncocked length" was about 70% of the free length.....Working night and day on the basis that the steel was adequate but the heat treatment inadequate, Reardon turned to austempering and time quenching. Quenching temperatures were gradually lowered from 1560 to 1510° F., quenching baths from 610 to 550° F., and times increased from 20 to 30 min. Rockwell hardnesses increased simultaneously from C-44 to C-52, but "impact" only from 12 to 16 ft-lb., so it became clear that drastic modification of heat treatment would not clear the trouble.....In desperation, Reardon leafed through all his technical books and magazines for notes on spring design and manufacture, and ran across the article in *Metal Progress* for March 1931 entitled "Why Did That Spring Break?" — taking the words right out of his mouth, as it were! It started a new train of thought: "These springs, at best, are *not quite* good enough. Can't we get a little more metal into them where the stress is greatest? Increasing the diameter of the round is out, but how about coiling *square* wire?" This not only increased its cross-section by 20% but put a lot more metal at the extreme fiber where the stresses are greatest, actually reducing the maximum by 12%. P.S. It worked. P.P.S. The Japs never got into Port Moresby.

For the want of a nail a kingdom was lost

Steel Making Methods

for More and Better Steels

A friendly debate took place at the last general convention of the as to the relative advantages of the openhearth and electric processes for the manufacture of alloy grades. Other important items contributing to our extraordinary production of steel ingots were also mentioned by others on the program. The information is no less timely then than now, for the demand is still for the utmost tonnage.

Basic Openhearth as a Producer of Alloy and Special Steels

By C. D. King
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United States Steel Corp. of Delaware
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ENTRY of this country into the present world conflict brought with it an enormously increased demand for alloy steels. Electric furnace capacity then in existence was inadequate to meet these requirements and it was therefore necessary to consider the openhearth process as a source for many quality steels formerly made in electric furnaces.

How well the openhearth has met this challenge is attested by the fact that during years 1940 to 1942 the basic openhearth increased its annual output of alloy steels by 4,000,000 tons, while in the same period electric furnace production increased 2,000,000 tons. In 1942, the basic openhearth process contributed 67% of the total alloy steel ingot production, and for the first nine months 1943 produced approximately as much as during the entire previous year!

Many of these steels require strict limits of cleanliness, soundness, and physical properties, and are subjected to many testing procedures such as magnaflux, etch tests, porosity and hardenability. To mention only a few of the grades of special steels which are now being successfully made in basic openhearth furnaces, we might list armor piercing shot, aircraft sheets, aircraft motor parts, tank and large gun parts, bullet core wire, valve spring wire, airplane wire, forging billets of many types, and a host of other special grades which, until recently, were considered by many to be largely within the province of electric furnaces. The basic openhearth process has so successfully demonstrated its capacity to produce huge quantities of alloy and special steels that the actual question arising is not whether this process is a factor in the production of such steels but, rather, what the underlying reasons are for this impressive demonstration.

Fortunately, American steel producers have been prepared for the war-time emergency as a result of previous advances in operating technique, involving furnace design and equipment, steelmaking practices, and personnel. Today, these efforts are bearing fruit.

Alloy steelmakers generally agree that a prerequisite for the successful production of these high grade steels is that the heats be worked, refined, and tapped *hot*. Heat is required for reducing the viscosity of the slag, this in turn raising the speed of refining reactions and the

cleansing actions. In order to accomplish this it is necessary to have dependable, sharp-working furnaces, permitting the melter to tap at temperatures of 3050° F. (and higher, if required). Sealing and insulating the furnace below floor level, and providing automatic draft regulation to minimize infiltration above floor level, have contributed to the sharp-working furnace to a large degree. In some plants the tendency for furnace performance to deteriorate rapidly toward the end of the campaign has been compensated, to a large degree, by using forced air as well as soot blowers, thereby maintaining efficient checker conditions. Considerable improvements have been effected in port and burner design, and atomization and combustion of fuels — all tending to improve flame propagation and control. Many operators also believe that other control equipment is useful in providing a controlled flame condition and an oxidizing atmosphere. It is because of these and other similar progressive practices that the high and uniform bath temperatures, pre-requisite for the production of alloy steels, are now possible in basic openhearth operations.

Similarly, improvements in refractories have kept step with changes in furnace design and also have contributed to the successful production of alloy steels. We have in mind, particularly, the use of improved refractories for bottoms, reducing the number of bottom boils and bottom troubles which are fatal to the production of alloy grade steels. The use of basic brick in many parts of the furnace system has also continued the efficient life of the furnace with a minimum of delays, thus giving more available time for producing steel.

Paralleling the development in construction and design is the greatly increased knowledge pertaining to steelmaking practices. Through the cooperation of technologists and plant operators, a wealth of data has been compiled and correlated, thereby permitting the establishment of correct procedures and prescribed practices. A few of these advances may be briefly mentioned; in general, they take the form of rapid methods of checking bath conditions, thus allowing slag and steel composition to be adjusted to meet requirements before the steel is tapped.

1. Careful selection of raw materials making up the charge.

2. Interpretation of the steel bath in terms of the slag, by checking the appearance, chemical composition or physical consistency of the slag, thereby enabling the melter to control harmful elements and absorb and retain the products of oxidation in the slag. (In passing, it might be remarked that we really *know* less about slag reactions today than we thought we knew five years ago.)

3. Greatly improved speed of accurate analytical methods by the use of such instruments as the Carbometer, Carb-analyzer, spectroscope, and similar devices, as well as more rapid chemical analysis. By these means the operator is made conversant with the state of the heat at any particular time, his rapid, rough-and-ready tests are accurately interpreted, and

Photograph by Van Fisher

corrective procedures can be applied where and when required. The operator, by controlling the rate of oreing and subsequent degree of oxidation of the heat, can be assured of a definite rate of carbon drop and he can attain the desired end result. In addition, these procedures assure the use of a minimum amount of deoxidizers required for specific purposes and, accordingly, result in the minimum amount of deoxidation products. Furthermore, these rapid, accurate analytical methods permit the diversion of the heat, if and as required, to other more suitable requirements.

4. The use of pyrometers for controlling tapping and pouring temperatures within closely prescribed limits which have been carefully determined as best practice.

Process control does not stop at the tap hole, since the same exacting practices are required in pit-side operation, be it ladle pouring rigging, ladle refractories, stopper setting, or the like. The close adherence to prescribed pouring speeds, the use of clean, prepared and coated molds at correct temperature — also involving proper mold design and hot tops — have been important additional contributory factors to the production of large quantities of basic openhearth alloy steels. In this connection, mention should be made of the use of "basket pouring", which permits higher working and tapping temperatures, allows for the rise of deoxidation products in the intermediate ladle, and pouring at prescribed lower temperatures, a practice resulting in notably cleaner steel at many plants.*

Process control is also exercised after the ingot is poured. It involves the proper track time before charging into pits, use of prescribed heating cycles in soaking pits, and equally carefully controlled rolling practice and subsequent heat treatment. These prominent factors, among many others not mentioned, have contributed to the successful application of the basic openhearth process to the production of alloy steels.

In addition, mention should be made of the recognition by the steel industry of the value of technologists, whereby operating experience and advances in metallurgical knowledge have been successfully coordinated.

The demonstrated ability of the basic openhearth process to meet the greatly increased demand for alloy steels has, to some extent, changed the previously existing sharp division between it and the electric process as far as its application for alloy steels is concerned. It is our opinion that today this demarcation is not the same as that which existed only a few years ago, either in degree or kind. By the same token, it is necessary to recognize that a counteracting influence appears to be in motion, in the form of larger electric furnace units which, with the use of molten metal, whether blown or decarburized, and generally faster melting practices, promises to increase the productive capacity per unit to an extent which offers some interesting competitive possibilities with openhearth steels for certain types of products in the post-war era.

Electric Furnace Quality Versus Openhearth

By Gilbert Soler

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Timken Roller Bearing Co.
Steel and Tube Division
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DURING 1942 and 1943 there was a definite shortage of electric furnace capacity for the production of high quality alloy steels. Because of this shortage, there has been a diversion of certain alloy steels to the openhearth furnace to a point where in mid-1943 the output of the electric furnace has been confined to products of the highest quality such as bearing steels, aircraft steels, toolsteels, stainless and heat resisting grades, gun steel and gear steel. That the requirements in these grades were concentrated in the basic electric furnace is, I believe, overwhelming evidence of the superior quality of electric furnace steel.

Nevertheless it cannot be said that any steel, just because it is melted in the electric furnace, is therefore superior to all other steel made. It is to be emphasized that the electric furnace provides a melting unit that has greater adaptability and is subject to much closer control than the openhearth furnace, but unless the operator makes use of these advantages he cannot expect to produce steel of superior quality.

*For a brief description and discussion of basket pouring, see "Critical Points" in *Metal Progress*, January 1944, page 106.

During the rapid expansion of electric furnace facilities between 1941 and 1943, plants have been built which utilize processes that deviate from the conventional concepts of electric steel making. Duplexing* — a process known in America for 30 years but uncommonly practiced here, in comparison with its common use in Europe, especially in Russia — and the use of hot metal from blast furnaces or cupolas are recent developments motivated by economic considerations and the demand for more tonnage. In the following discussion openhearth steel is compared to electric furnace steel made by the conventional cold charge, two-slag practice.

The electric furnace as a melting unit provides certain advantages in the steel making technique that can be utilized in consistently producing high quality steel. The standard grades of electric steel are generally of an analysis that could be produced in the basic openhearth, but are required to meet specifications for cleanliness or physical properties. The latter are under strict control by:

1. Heat input and control.
2. Slag practice.
3. Tapping and teeming practice.

Heat Input and Control — The electric furnace provides a ready source of quick, available heat under close control of the furnace operator; he can regulate the heat input to the furnace by suitable voltage tap settings and current adjustments. Heat input to the openhearth is at a slower rate, and subject to less positive control; the openhearth first helper utilizes preheated air from the checkers along with his fuel to obtain the proper flame temperature, and he must constantly regulate fuel flow, air flow, steam pressure, and furnace pressure, and at the same time keep his checker temperatures in balance.

In the electric furnace heat is transferred directly to the charge or molten bath by means of the arc which is formed between the electrodes. Temperatures of 6000° F. are estimated to exist in the *path* of the arc. During the early stages of the heat in a properly charged electric furnace the electrodes will bore down through the scrap, forming pools of molten metal, thus allowing the charge to melt from the bottom upward. This insures a more uniform temperature throughout the molten bath when the heat is entirely melted. During the melting period high temperatures can be used because the scrap charge protects the furnace refractories from the excessive radiation. In the openhearth furnace heat is transferred to the top of the charge directly from the flame and by radiation from the incandescent furnace roof; it is obvious that the melting point of the roof refractories imposes a serious limitation upon the rate that heat can be put into the charge.

Electric heat is "clean" heat, in the sense that carbon from the electrodes is the only for-

*For a brief description of Republic Steel Corp's. notable plant for duplex steel, see "Critical Points" in *Metal Progress*, January 1944, page 106.

eign material that can enter the melt from this source. This is usually not a problem during melting, as ore will be added later to remove this carbon as well as the far larger amount in the iron and steel scrap of the charge. After the bath is melted little difficulty is encountered with carbon pick-up from the electrodes. On the other hand, fuels used in the openhearth furnace usually contain sulphur, and it may be present in sufficient amount to hinder the removal of sulphur from the metallic bath.

The electric furnace utilizes high rates of heat input during melting, but during refining the bath can be closely maintained at temperature with relatively little heat input. The openhearth furnace is limited in the rate of heat input, consequently a uniformly high and correct metal temperature is not obtained until close to tapping time.

Slag Practice — Steel can be produced in the electric furnace either under oxidizing or reducing slags of various degree, or any combination or succession of such slags. The slag volume is low (amounting to 2 to 4% of the metallic weight of the bath) so its composition can be quickly adjusted by relatively small additions. Furthermore a slag can be easily removed and another slag made up in short order. Electric furnace slags flux readily and they rapidly approach equilibrium with the steel bath. The openhearth furnace does not have this flexibility of control and change in slag practice; it can only utilize oxidizing slags and the slag volume is high (amounting to 10 to 12% of the metallic weight of the bath).

In melting down under oxidizing slags the electric furnace, with a definite regulation of heat input, provides better control of carbon at meltdown and later while working the bath. This results in cleaner steel and closer chemical control.

The electric furnace heat is finished under a reducing slag which allows alloy additions to be made in the furnace without undue loss by oxidation. In the openhearth furnace extreme care must be taken in blocking the heat, making alloy additions quickly and tapping into the ladle, for oxidation losses are relatively high. (Certain alloys and deoxidizers such as vanadium, aluminum, titanium and silicon must be added to the ladle, when making openhearth heats.) It can readily be seen that closer control of final chemistry can be obtained in the electric furnace. Furthermore sufficient time for the melting and solution of alloy additions can be provided in the electric furnace, so that high alloy additions can be made which would not be possible in the openhearth furnace due to the short period available between block and tap.

In openhearth practice some phosphorus may revert from slag to bath, on addition of the block, and later during teeming. In electric furnace practice the first or oxidizing slag is removed so there is no danger of phosphorus reversion.

Tonnage Steels

Aside from the "quality" steels, represented by alloy grades, some attention was given to other steelmaking processes for so-called tonnage steels. Since only a reporter's notes are available on this part of the discussion, no direct quotations from the addresses will be made.

It was brought out that a steady improvement in overall plant efficiency has occurred since World War I through betterments in general furnace design and plant layout. In the better plants, openhearth production of common steels from 100-ton or larger units has increased about 50% in that time, and in the face of sharply rising prices of all items entering the cost, the selling price has kept at a remarkably low figure. Since the outbreak of the war, however, we have definitely lost plant efficiency in fulfilling the demand for more and more tons of ingots. This has come about through shortened furnace campaigns and abridged rebuilding practices and increased costs, or the increasing frequency and higher costs of hot maintenance or running repairs.

The munitions program has required a 25% increase in openhearth capacity, which was achieved by additional new furnace capacity, reconstruction and enlargement of existing units, and operating furnaces a greater percentage of available time. Inefficient units had been eliminated and the net result was fewer furnaces and more output.

Increased hot metal charges, accurate timing of charging sequences, higher iron charges, increase in number and size of ladles, rebuilding of pouring stands, larger charging pans for light scrap, adequate supply of charging cars and pans, proper distribution of scrap in furnace, blending of heavy and light scrap to maintain uniform bulk and exposed surface, use of optimum percentage of ore in charge, use of sinter to augment ore with high metal charges — all these items contributed to higher rates of production.

When an efficient openhearth plant is mentioned it brings to many minds a beautifully engineered and constructed mechanism as a vehicle for the production of steel, rather than a hot and dirty apparatus from which steel is produced through the action of the minds, supervision and labor of a large group of men.

When the operations are analyzed into animate and inanimate factors it will be concluded that the combined personnel in the melt shop from general superintendent to pit laborer, the supporting workmen in stocking, stripping, soaking pit departments will be certainly graded as 50 on

The finishing of an electric furnace heat under a reducing slag enables the melter to remove considerably more sulphur than is possible in ordinary openhearth practice. The reducing slag also diminishes the oxygen content of the metal to a low value, so that a smaller amount of deoxidation products is formed when the final deoxidizers are added, and those deoxidation products which are formed have a greater chance of leaving the steel and rising to the slag than the analogous substances formed in the openhearth ladle. For these reasons less sulphide and oxide inclusions are usually found in well made electric steel than in openhearth steel of the same grade.

Tapping and Teeming Practice — When the electric furnace is ready to tap, the furnace is tilted and the heat poured into the waiting ladle. Steel can be tapped from under the slag, or slag and steel can be tapped together if desired. At times, when an openhearth furnace is ready to tap, some delay may result due to a hard taphole and the tapping time may be slow or fast depending on conditions which are at least partially beyond the control of the openhearth melter.

Deviation from the ladle analysis between various ingots of the heat is less for electric furnace steel than for openhearth heats. In electric heats all additions can be made to the furnace and complete mixing of the metal is obtained during tapping. In openhearth heats, where additions are made to the ladle, less mixing action is obtained and some steels must be re-ladled to prevent excessive segregation.

A properly made reducing slag in the electric furnace is practically in equilibrium with the metal at tapping time and little difference will be found between the chemistry of the various ingots of the heat as no reaction will take place between slag and metal during pouring. Openhearth heats may show some variation between the various ingots of the heat, as the highly oxidized openhearth slag is not in equilibrium with the steel in the ladle.

Summary — In summarizing it can be concluded that the electric furnace provides these certain advantages over the openhearth furnace which, if utilized, result in a higher quality product:

1. Closer chemical analysis limits can be maintained, and greater uniformity of chemistry obtained between various ingots of the heat.

2. Grain size, abnormality, and hardenability are more uniform and subject to closer control.

3. Cleaner steel can be produced containing less deoxidation products.

4. Lower sulphur and phosphorus contents can be obtained.

5. Standard practices can be established and more easily followed, insuring uniform quality from heat to heat.

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a scale of 100 for all factors. The remaining 50 points are divided between quality of raw materials, excellence of furnace design, and general plant layout. Since much of these latter categories depend on personnel, and are functions controlled by men, it is obvious that it is men — not plant — brains and desire that is maintaining our amazing steel production rate in the face of all difficulties.

Acid Openhearth Steel

The acid openhearth produces only approximately 1% of all our alloy steel. The reason for the low production figure is, of course, that phosphorus is not removed in acid openhearth refining, and the process is therefore limited to low phosphorus charges which are scarce and expensive. The question arises as to why the process is used at all.

The process is suited for production of special steels because:

1. The simplicity of the melting operation is adapted to production requirements of small casting plants.

2. The low inclusion content of good acid steel enables large forgings to be made to specifications requiring high transverse ductility. It should be remembered in this connection that the greater the reduction by forging, the greater the difference in ductility when measured with and across the grain. This damage to transverse ductility, so-called (and measured by the reduction of area in a tensile test piece) is due to the spreading out into flat zones of the original non-metallic inclusions. Therefore a piece requiring high transverse ductility should be forged enough to break up the ingot structure, and to promote subsequent heat treatments, but little more.

3. Less trouble is encountered with cooling cracks in forgings made from properly refined acid openhearth steel and shatter cracks are rarely observed in such steel. The reason for this relative immunity of acid steel has never been satisfactorily explained.

Acid openhearth steel contains less inclusions of the harmful oxides of phosphorus and sulphur. Cleaner microstructures are obtained. Acid steel "fibers" more readily than basic openhearth steel. The opportunity for absorption of hydrogen gas, which has been connected with certain defects associated with inferior mechanical properties, is not as great when melting in the acid openhearth. Lime additions are not made and the acid oxide slag provides better protection to the molten bath.

Since the acid openhearth is confined to production of certain special steels, the practice has developed principally as a result of local experience, and the technology of the process generally has not advanced as far as for the basic process.

Bits and Pieces

Metallurgicus's

Own Department

Etchant for Silver Solders

When a metallographic specimen of silver solder is etched with the commonly used ammonium hydroxide and hydrogen peroxide reagent, the dark and light constituents of the microstructure are brought into good contrast but the dark constituent is very likely to be overetched with the result that the details of its structure are lost.

A much more satisfactory etchant, both from the standpoint of convenience and results, is a 2% ferric chloride solution. This acts slowly enough to permit the structural details of the dark constituent to be revealed clearly. The desired degree of contrast is obtained by controlling the etching time, which is generally in the range of 5 to 30 sec.

A stronger solution of ferric chloride etches too rapidly and in much less controllable fashion. Acidifying the ferric chloride with hydrochloric acid, as is common practice for copper alloys, is not necessary since it does not improve the action on silver solder. (L. P. Tarasov, Research Laboratories, Norton Co.)

To Identify Cd, Sn and Zn Coatings

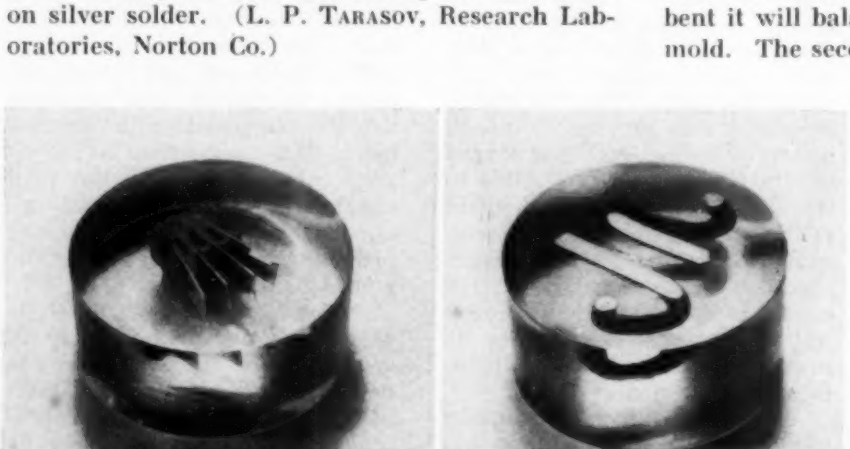
Here's something to add to the other rapid methods of distinguishing metals that look alike. This time it's cadmium, tin and zinc plates or coatings:

Immerse the sample in a solution of one part commercial hydrochloric acid and one part water. If a rapid reaction takes place the metal is zinc. If no obvious reaction occurs, hold a piece of Armco or electrolytic iron in contact with the sample beneath the surface of the acid solution. If rapid gas evolution takes place at the interface of the iron and acid, the metal is cadmium. If no obvious gas evolution of this nature occurs, the metal is tin.

A preliminary trial of the method with known samples will readily demonstrate its applicability to the user. (Birger L. Johnson, Jr., Pittsfield Works Laboratory, General Electric Co.)

Mounting Small or Fragile Specimens

Small and fragile specimens are frequently difficult to mount for metallographic examination, even when using lucite or similar thermosetting materials. Two examples of successful methods are shown. The first is a method of preparing cross sections and longitudinal sections of fine wire in a lucite mount. If the wire is correctly bent it will balance properly and lie quiet in the mold. The second shows a group of razor blades in a lucite mount. The pieces of blade are gripped by folds in a strip of sheet lead, and pinched tight with pliers. In mounting samples like this (light wire gauze is another example) the lucite should be thoroughly heated before pressure is applied; if compressed while plastic it will carry down and distort a fragile specimen. (Gordon Sproule, Professor of Metallurgy, McGill University)



Effective Cleanser for Aluminum Prior to Spot Welding

An important time saver in the assembly of aluminum alloy sheet by spot welding has been devised by Northrop Process Engineering Dept., in the form of a one-step cleaning and etch method, applicable to assemblies of details, jigged and held together temporarily by fasteners of various sorts. The liquid is composed of phosphoric acid and a petroleum derivative used as a solvent cleansing agent, and procurement data will be furnished any producer of war material on written application. The bath operates at room temperature and has about one-third the surface tension of the ordinary alkali etching solutions, and therefore is drawn into all joints

Placing an Assembly in the Etch Tank to Ready It for Spot Welding

and faying surfaces by capillary action. It is handled in lead-lined tanks.

Assemblies of duralumin or of duralumin and alclad are immersed no longer than 10 min. (individual parts of alclad require from 10 to 16 min., increasing with the gage, and are timed by the appearance of the first trace of grayish black film.) After etching, the assembly is plunged into an air-agitated tank of water at 70° F., then dried in air blast or by a bank of infra-red lights. Welding can proceed immediately. Cleaned articles are handled with neoprene gloves to avoid fingerprints.

Strength of solution should be checked daily by titration tests. At week ends the solution is filtered by pumping through a cartridge containing sawdust and excelsior. The original solution, with periodic sweetening, has been used by Northrop for two and a half years.

Strength and uniformity of the welds made on assemblies cleaned in this manner have been amply proved by hundreds of tests during the past two years. Electrode fouling has also been greatly reduced; 12,000 consecutive spots have been made on assemblies cleaned and etched with this solution without cleaning the tips, and without lowering the quality of the spot welded joints. (T. E. Piper, Northrop Aircraft, Inc.)

Short Cycle Anodizing

A short anodizing process has been developed by Boeing Aircraft of Canada Ltd. and approved for use in its Vancouver plant both by the Royal Canadian Air Force and the U. S. Navy for aluminum and its alloys containing less than 5% copper. Coupled with a solution control method, it gives a slightly better anodic film than the 35-min. process in general use in the U. S. A. While patents have been applied for, full details will be furnished to war contractors, and royalty-free licenses issued for the duration.

The solution contains between 3 and 5% of hexavalent chromium, and not less than 1.5% of free chromic acid. Accurate chemical control is essential for constant results and minimum consumption of acid. The bath must be thermostatically controlled at 96° ± 4° F.

Proper and complete cleaning before anodizing is *essential,* immediately before immersing in the tank. No special splines, hangers or clips are required. Voltage cycle is as follows: Increase from zero to 40 volts in 10 min. and hold for 5 min. Step up from 40 to 50 volts in 3 min. and hold for 2 min. Other details of the process are in accordance with U. S. Navy specification PT19.

This new Boeing anodizing process will produce anodized surfaces passing the salt spray tests prescribed in the U. S. Army-Navy specifications QQ-A-696a and AN-QQ-S-91. It also passes satisfactorily the 30-day intermittent salt spray simulative test in general use in England. It has doubled the capacity of the anodizing equipment available when using the 35-min. American process as detailed under specification PT19, and more than tripled the capacity available when using the 60-min. English Bengough-Stewart process DTD910A. At the same time it consumes only 42% of the power and 44% of the chromic acid used with specification PT19 and only 28% of the power and 20% of the acid used with DTD910A.

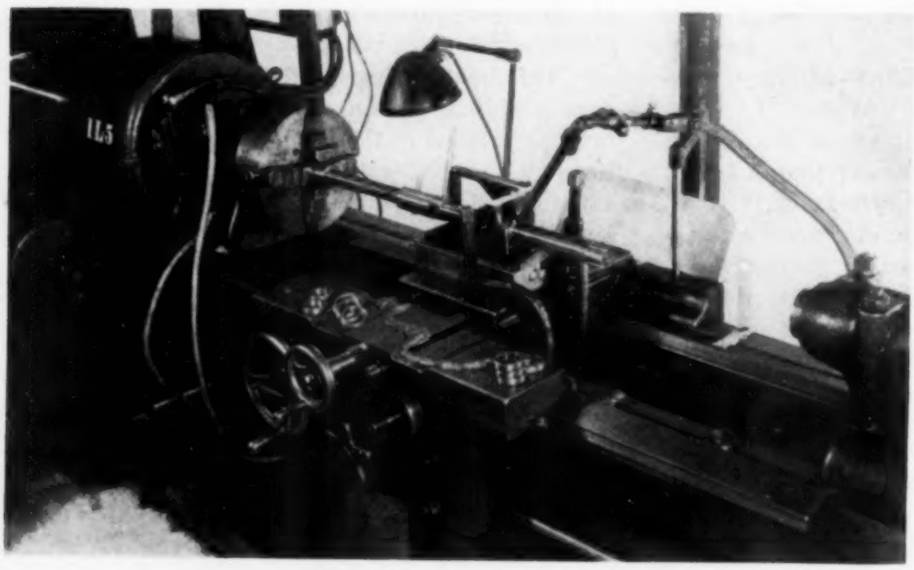
When we used the Bengough-Stewart process the Sea Island plant consumed 8570 lb. of chromic acid monthly costing 25¢ per lb. and the department was charged with $600 for electric power (0.09¢ per kw-hr.). On the basis mentioned above the monthly savings as of mid-1943 were $2142. Furthermore the short cycle has avoided the installation of new tanks and electrical equipment. (GEORGE MAYNARD, Director of Technical Control, and A. A. BAUDAT, Equipment Engineer, Boeing Aircraft of Canada, Ltd.)

A Lathe Converted Into a Broaching Machine

WE WERE CONFRONTED with the necessity of broaching some lugs in the interior of some 2-in. rings, yet we had no standard broaching machines in the shop. However, as shown in the photograph, we were able to adapt a lathe very nicely. Shown from left to right are the chuck holding a bronze nut, a lead screw, a steel sleeve attaching the broach, the work holder on the tool rest, and the projecting end of the broach.

The lead screw shown in the photograph was borrowed from another lathe and has a diameter of 1⅜ in. The only work done to this lead screw was a ⅜-in. hole drilled in the bearing end to accommodate the broach attachment. A bronze nut of the same screw was used inside the four-jaw chuck. The nut had a 1-in. shoulder behind the chuck jaws. A 3-hp. motor of 1425 r.p.m. pulled the broach through the work in 20 sec. at full speed. The reverse was a trifle slower as we only used the standard reverse on the lathe. Material broached was machine steel and about 0.180 in. was removed in one stroke.

The broaching jig was welded from 1 in. cast iron with a square counterbore to allow aligning the ring. No clamp attachment was necessary to hold the ring during broaching; the piece is allowed to float and so centralizes itself. The broaching jig, as can be seen, was simply bolted to the compound feed rest of the lathe with T-bolts. A 2-in. diameter bar was used to bolster the cross-feed and prevent the work being pulled into the jaws. Two C-clamps clamped the cross-feed rigidly to the bed of the lathe. A portable coolant pump, as shown in the photo at the foot of the page was attached. (R. C. NEWTON, Harrington Tool & Die Co.)



Identifying Nickel in Aluminum Alloys

RESPONDING to Metallurgicus's request some time ago for information on quick and reliable methods for discriminating between nonferrous metals of similar color and hardness, yet of different composition, we have found the following method very satisfactory for the separation of nickel-free aluminum alloys from those containing no nickel.

Equipment necessary is some lintless blotting paper cut into ½ by 2-in. strips, and an electrograph consisting of

(a) Four No. 6 dry cells.

(b) Two small battery clips (approximately 2 in. overall length).

(c) One graphite or carbon rod (approximately ¼ in. diameter by 3 in. long).

(d) Insulated flexible wire for making connections.

Connect the four dry cells in series and attach suitable lengths of insulated flexible wire to the positive and negative poles. Attach the small battery clamps to the ends of the leads. Insert the carbon rod into the clamp attached to the negative lead from the batteries.

Solutions needed are

No. 1. Dilute nitric acid (1:1).

No. 2. Concentrated ammonium hydroxide.

No. 3. 1% alcoholic dimethylglyoxime.

Procedure — Attach specimen to clamp from positive terminal of batteries. Place one drop of

solution No. 1 on a strip of the blotting paper allowing 1 to 5 sec. for absorption. Place the paper on the specimen and contact with the carbon or graphite electrode directly on the wet spot, exerting 10 to 20 lb. pressure on the electrode. Maintain this contact for approximately 5 sec. Remove paper and apply 1 to 2 drops of solution No. 2, followed by 1 to 2 drops of solution No. 3. A pink fleck will develop if the specimen contains 0.75% nickel or more.

Notes — This method was used successfully for separating aluminum meeting Federal Specification AN-QQ-A-390, Class 2, from an alloy containing 0.75 to 1.00% nickel.

It is believed that this test will be satisfactory for separating alloys such as Alcoa 18S, 32S, 142 and A355 from other aluminum alloys containing nickel as an impurity.

The normal amount of iron, and as much as 4.5% of copper, have no apparent effect on the spot obtained with dimethylglyoxime. (L. J. HIBBERT, Materials Laboratory, National Cash Register Co.)

Cut Gates and Risers Closely

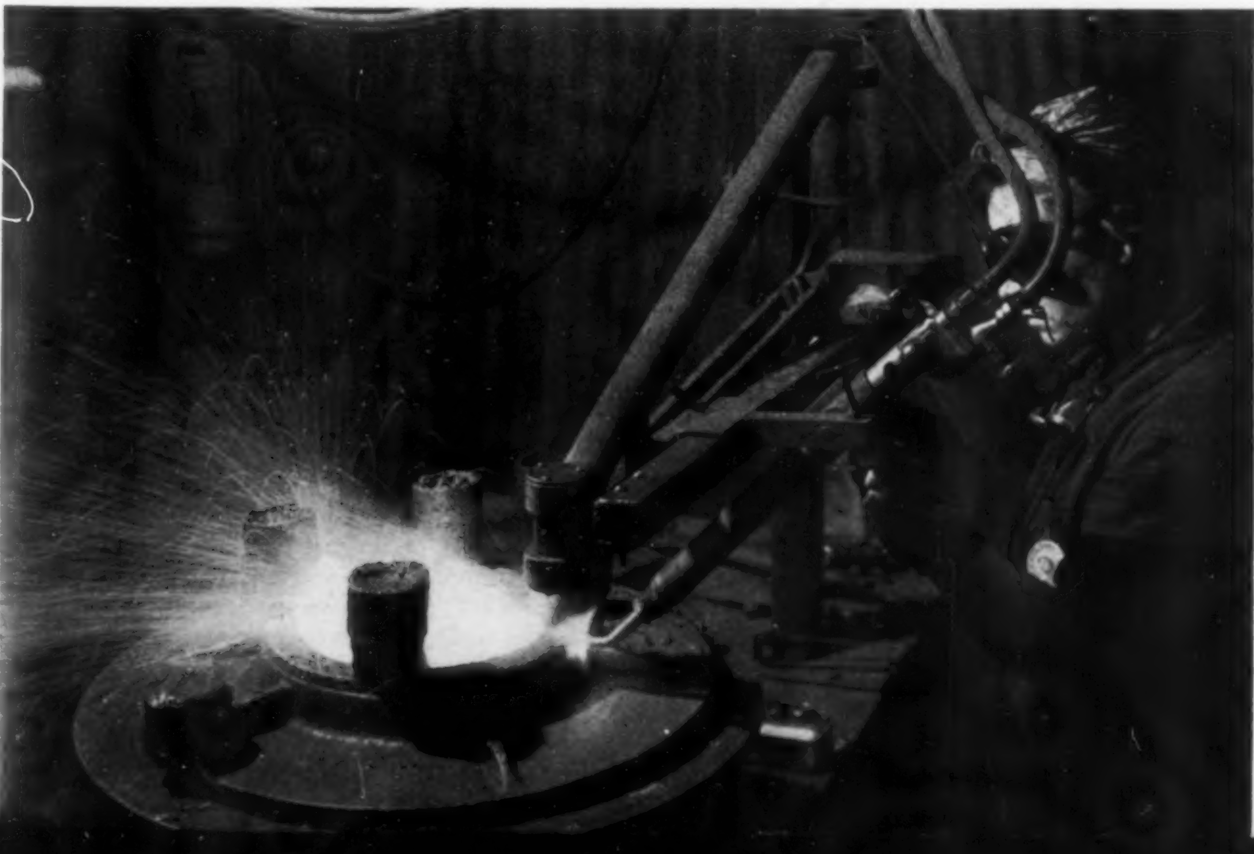
A SIMPLE FIXTURE, such as the one illustrated, becomes in effect a special machine for flame cutting gates and risers from heavy circular castings, such as clutch plates and bodies. It will do a better job than hand cutting because it makes a closer marginal cut, leaving only the barest minimum of metal to be ground off. Thus, grinding can be reduced at least 50%. Secondly, machine gas cutting avoids gouging the surface of the casting itself — gouges which must be filled with weld metal and ground flush. Lastly, operator fatigue is diminished.

The photograph shows a woman operator cutting risers from a clutch plate casting at one of the large foundries in the Chicago region. A light hoist places the casting on a turntable which is rotated by a variable speed motor. The machine gas cutting torch is mounted on an arm at 45°, adjustable either up or down or in a radial direction. The speed of cutting on this particular job is 16 in. per min., and the operator handles between 50 and 60 castings in an 8-hr. day. By merely turning the cutting torch 180° in its clamp, the flame is directed vertically downward, and can clean out central cores or trim extra metal from any circumference. (GEORGE BELLEW, Foundry Specialist, Air Reduction Sales Co.)

Identification of Specimen Mounts

BECAUSE of the hardness and smoothness of the more common plastics used for metallurgical specimen mounts, such as the urea-formaldehyde type, it is somewhat difficult to write the number of the specimen on this material in a way which will not rub off.

One method which has proven quite satisfactory is to use a vibrating type of electric marking tool to cut or scratch the identification mark or number on the back of the mount. If the plastic is white, an ordinary pen may be used to fill in the scratch with India ink, which will flow in by capillary attraction. (R. L. DUFFNER, Metallurgist, General Cable Corp.)



A Formulation of the Carburizing Process

**By Floyd E. Harris
and Wilson T. Groves**
Furnace Engineer and
Metallurgist, Respectively
Buick Motor Division
General Motors Corp., Flint, Mich.

In former articles in his series on the process of carburizing steel in gas, Mr. Harris approached the problem by first carburizing steel samples and determining the carbon content at various depths by chemical analysis, and then showed how the experimental concentration-depth curve was related to the theoretical curve for diffusion of carbon in gamma iron. Sufficient generality was observed in these experiments so that the converse operation is now possible: A generalized formulation of the carburizing and decarburizing processes is made mathematically, and the predicted results then check satisfactorily against a series of experimental determinations.

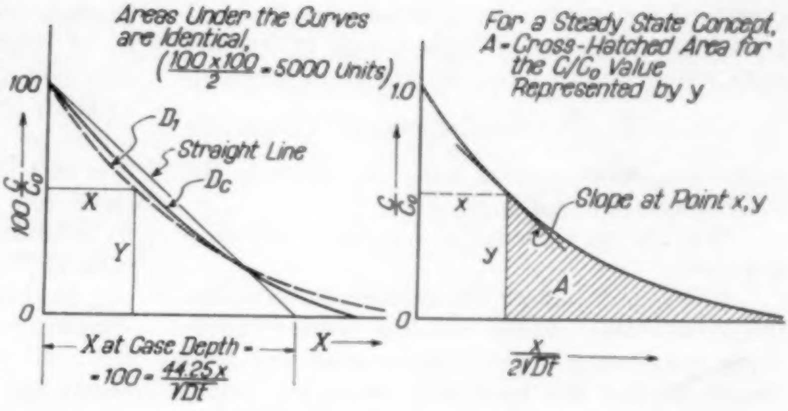
DURING the past two decades, innumerable discussions have appeared in the literature about the process of adding carbon through the surface of steel bars which have initially a low carbon concentration, thereby obtaining carbon gradients. The profusion of recorded data is of itself a tribute to recent developments in this, perhaps the oldest of metallurgical arts. However, the information is largely of a "practical" nature, each applying to its particular set of conditions, and as practices become increasingly discriminating, it seems imperative that the mechanism of the process be subjected to a more rigid scrutiny. This will be the aim of this paper.

Such a formulation must depend upon the diffusion rates of carbon in iron and, specifically to obviate phase boundary changes, all test conditions will be limited to the flow of carbon in gamma iron. The method to be used for analyzing these rates appeared in the June 1944 issue of *Metal Progress,* where an application was made for a typical carburizing gradient. That analysis indicated that, at least for the conditions imposed by commercial gas carburization, the diffusion rate is a straight line function of the carbon concentration. (See Fig. 4 of the June article.) Hence we propose, for clarity of exposition, to divide this problem into two parts:

First, we will apply this method in a strictly mathematical and graphical manner, assuming equal increments of increase in the diffusion rates for corresponding increases of carbon concentration. In a generalized form we will thereby construct ideal gradients for such varying changes of conditions as may be imposed. From these theoretical gradients we will derive, among other things, an expression which will be correlated to the *direction* of carbon flow with respect to the surface. (When the flow is inward we carburize, and when the flow is outward we decarburize — an action ordinarily to be avoided.) Since the decarburizing gradient is influenced by the relationship of concentration to the direction of flow in a manner opposite to that found in the carburizing process, we will then be ready to devise the experimental conditions for checking the authenticity of the method.

Second, we will present experimental data from carburizing and decarburizing operations, to demonstrate the constancy with which bound-

Fig. 1 — Carbon Gradients for Assumed Steady State. In the left hand sketch $X = 100$ at $x/2\sqrt{Dt} = 1.13$



ry conditions may be maintained. From similar data a method will be shown by which the range of diffusion coefficients with concentrations may be easily and accurately obtained for any given steel composition. Values thus derived will be compared with the corresponding ones found in the previous article analyzing a typical carburizing gradient, and this agreement will provide a powerful argument for the general applicability of the mathematical solution.

Part I. Development of Method and Its Application

"Flow of carbon in gamma iron is from higher to lower concentrations" states a matter of common experience. The mathematical analysis will assume that the diffusion rate is dependent on the concentration — that is, differs in low carbon areas from high carbon areas — and also that this rate increases in a regular manner with increases in concentration. Since the preceding paper (June 1944 *Metal Progress*, page 1111) indicates both assumptions to be true, we now repeat a method equation stated on page 1115, and define, briefly, the notation:

$$(\text{Relative } D_c)^{3/2} = \frac{\frac{A_c}{C/C_o} \text{ for the actual } D_c \text{ gradient}}{\frac{A_1}{C/C_o} \text{ for hypothetical } D_1 \text{ gradient}} \qquad \text{Equation (1)}$$

The significance of A values and the coordinates are shown in Fig. 1, a reproduction of Fig. 2 of the June article. D_1 describes a gradient that transports through the surface an amount of carbon equal to that which would occur if the diffusion rate varied with concentration. The latter variable rate is denoted by D_c. This theoretical

Table I — Properties of Theoretical Concentration-Depth Curve (D_1)

Plotted on coordinates $Y = 100\frac{C}{C_o}$, $X = 100$ at $\frac{x}{2\sqrt{Dt}} = 1.13$

Total area under curve = 5000

A_1 = area to right of ordinate for a given $\frac{C}{C_o}$ value.

$\frac{A_1}{C/C_o}$	Slope	$\frac{A_1}{C/C_o}$	Slope	$\frac{A_1}{C/C_o}$	Slope	$\frac{A_1}{C/C_o}$	Slope
5000	1.2732	3910	1.0853	3520	0.9055	3130	0.6693
4950	1.2729	3900	1.0815	3510	0.9001	3120	0.6627
4900	1.2720	3890	1.0776	3500	0.8946	3110	0.6561
4850	1.2704	3880	1.0737	3490	0.8891	3100	0.6495
4800	1.2680	3870	1.0697	3480	0.8835	3090	0.6428
4750	1.2651	3860	1.0657	3470	0.8779	3080	0.6363
4700	1.2613	3850	1.0617	3460	0.8723	3070	0.6296
4650	1.2567	3840	1.0576	3450	0.8667	3060	0.6229
4600	1.2514	3830	1.0535	3440	0.8610	3050	0.6162
4550	1.2454	3820	1.0494	3430	0.8553	3040	0.6095
4500	1.2385	3810	1.0452	3420	0.8496	3030	0.6028
4475	1.2346	3800	1.0410	3410	0.8438	3020	0.5961
4450	1.2306	3790	1.0367	3400	0.8380	3010	0.5894
4425	1.2263	3780	1.0324	3390	0.8322	3000	0.5827
4400	1.2220	3770	1.0280	3380	0.8263	2990	0.5760
4375	1.2171	3760	1.0236	3370	0.8204	2980	0.5693
4350	1.2122	3750	1.0192	3360	0.8144	2970	0.5625
4325	1.2071	3740	1.0147	3350	0.8085	2960	0.5557
4300	1.2018	3730	1.0102	3340	0.8025	2950	0.5489
4275	1.1962	3720	1.0056	3330	0.7964	2940	0.5421
4250	1.1903	3710	1.0010	3320	0.7903	2930	0.5353
4225	1.1841	3700	0.9963	3310	0.7842	2920	0.5285
4200	1.1777	3690	0.9916	3300	0.7780	2910	0.5217
4175	1.1711	3680	0.9869	3290	0.7718	2900	0.5149
4150	1.1644	3670	0.9821	3280	0.7655	2890	0.5080
4125	1.1575	3660	0.9773	3270	0.7592	2880	0.5011
4100	1.1501	3650	0.9724	3260	0.7529	2870	0.4944
4075	1.1424	3640	0.9675	3250	0.7466	2860	0.4877
4050	1.1343	3630	0.9626	3240	0.7403	2850	0.4810
4025	1.1260	3620	0.9576	3230	0.7340	2840	0.4743
4000	1.1178	3610	0.9526	3220	0.7277	2830	0.4684
3990	1.1143	3600	0.9475	3210	0.7213	2820	0.4630
3980	1.1108	3590	0.9424	3200	0.7149	2810	0.4565
3970	1.1073	3580	0.9372	3190	0.7084	2800	0.4500
3960	1.1037	3570	0.9320	3180	0.7019	2790	0.4432
3950	1.1001	3560	0.9268	3170	0.6954	2780	0.4363
3940	1.0965	3550	0.9215	3160	0.6889	2770	0.4294
3930	1.0928	3540	0.9162	3150	0.6824	2760	0.4225
3920	1.0891	3530	0.9109	3140	0.6759	2750	0.4156

curve is related to the probability integral, as explained in the former articles, and Table I (an expanded version of Table I, page 1113 of the June issue) gives values, derived from probability tables, of $\frac{A_1}{C/C_o}$ versus slopes. Coordinate values are dimensionless units as shown in the left hand sketch in Fig. 1.

We are now ready to construct the ideal gradient.

In the analysis of the carburizing gradient, the coordinates chosen for the concentration-depth curve were non-dimensional and were chosen so that the total area under the actual gradient D_c equalled the area under the hypothetical gradient of equal transport D_1. There are values greater than one, but less than three m[ay] be chosen for $D_{C/C_o=1}$ or w, as shown by the fa[m]ily of lines of equal slope in Fig. 2. Actual[ly] only one of these will enable us to construct [a] carbon-penetration curve which fits the requir[e]ments we have set up for it. We will show ho[w] this was determined by trial computations, an[d] chart this gradient shortly. First, however, l[et] us consider the significance of these combin[a]tions of D_{C/C_o} values in terms of D_1.

In Fig. 2, three straight lines are draw[n] showing possible variances of Relative D_{C/C_o} wit[h] C/C_o, all for a ratio of three. The center on[e] shows the correct relationship (and it will con[-]struct a carbon concentration gradient curv[e] subtending an area equal to that under the D_1

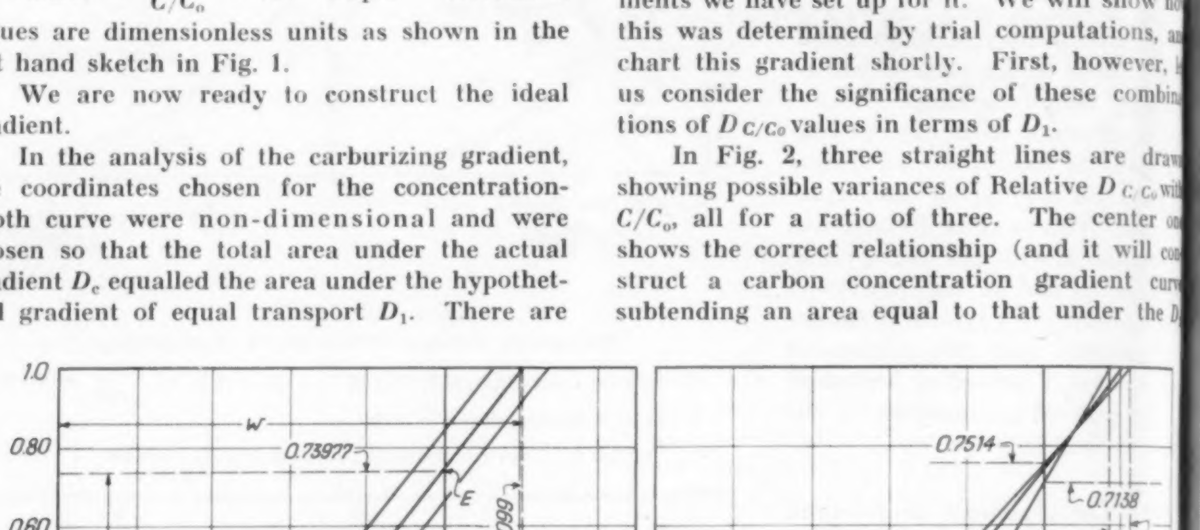


Fig. 2 — At Left Is Family of Lines All Conforming to Requirement that $D_{c/c_o=1} \div D_{c/c_o=0}$ Equals 3; Coordinates are Noted for Condition That Area Under Derived Diffusion Gradient Curve Equal Area Under Theoretical Curve. At right are shown data for ratios of 2 and 4 which also fulfill these conditions

but two values of the ordinate C/C_o for which the A value, as used in this method, is equal for the two gradients, namely at $C/C_o = 1$ and at $C/C_o = 0$, when $A = 5000$ and 0 respectively.

We choose the point, $C/C_o = 1$ to initiate the gradient-curve construction. We also choose an arbitrary ratio for this construction, namely, the gradient at the surface is three times as large as the gradient at the core. In symbols:

$$\frac{w}{u} = \frac{\text{Relative } D_{C/C_o=1}}{\text{Relative } D_{C/C_o=0}} = 3$$

This choice of 3 for the ratio is reasonable, for in Fig. 4 of the June article it was shown that D_o relative to D_1 at the surface of carburized S.A.E. 1020 is 1.2 and at the inner limit of case depth is 0.4. For carburization, Relative $D_{C/C_o=1}$ (noted on Fig. 2 as w) must obviously be greater than unity, and Relative $D_{C/C_o=0}$ (or u) less than unity, since the diffusion values are dimensionless and expressed relative to unity.

Now for a ratio of three, any number of gradient, namely 5000). This line intersects th[e] D_1 line, representing a D of unity for all C/C_o values, at $C/C_o = 0.73977$, the point marked E and we state:

$$D_{C/C_o} = D_1 \text{ at } C/C_o = 0.73977$$

Since this value E for C/C_o has such a speci[al] significance in this solution, a brief mathematic[al] expression is

$$u = \text{Relative } D_{C/C_o=0} = 0.4033$$
$$w = \text{Relative } D_{C/C_o=1} = 1.2099$$
$$D_{C/C_o} = D_1 \text{ when } C/C_o = \frac{1-0.4033}{1.2099-0.4033}$$
$$= 0.73977 = Z$$

Table II shows a complete tabulation for a[n] ideal gradient computed on the foregoing prin[-]ciples — where the diffusion rate is a linear func[-]tion of the concentration, and where this rate a[t] the surface is three times the rate for the initia[l] concentration, and where Relative $D_{C/C_o=1}$ i[s] taken at $C/C_o = 0.73977$. The compilation is sim[-]

ple, once the D_1 point (where Relative $D_{C/C_0} = 1$) is determined. Column II lists the Relative D_{C/C_0} values, which decrease, as will be noted, in a regular manner with equal decrements of C/C_0. The constant tabular difference is $(1.2099 - 0.4033) \div 20 = 0.04033$. These figures in Col. II are raised to the three-halves power in Col. III. The rest of the figures are computed line-by-line, rather than column-by-column, as shown in the construction (Fig. 3).

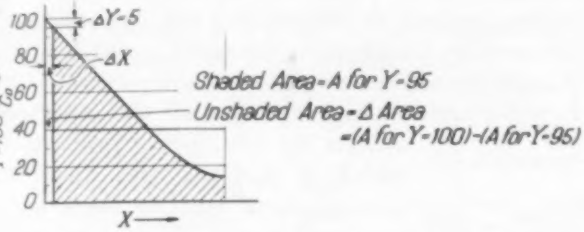


Fig. 3 — Construction Showing Method of Figuring Col. IV, VIII and IX in Table II

Column IV for A is the area under the gradient curve to the right of the ordinate in question; for 100 $C/C_0 = 100$, $A = 5000$ by assumption (see the article on "Case Depth" in *Metal Progress* for August 1943). Column V is had by dividing A by the corresponding value of C/C_0; in the first line it is obviously $5000 \div 1.00 = 5000$.

$\frac{A_1}{C/C_0}$, the corresponding value for the D_1 gradient, is found in Equation (1) by dividing $\frac{A}{C/C_0}$ by (Relative $D_{C/C_0 = 1})^{3/2}$, and for the first item in Col. VI this is $5000 \div 1.33084 = 3757$. The value of slope (Col. VII) is then taken from Table I, by interpolation; the figure is 1.0223. Given the value of the slope of the gradient curve we are in a position to compute the decrement of area (see Fig. 3) as follows:

$\triangle Y$ (or the tabular difference in Col. I) is 5. Since the slope or tangent of the curve is $\frac{\triangle Y}{\triangle X}$ we have

$$\triangle X = \frac{\triangle Y}{\text{Slope}} = \frac{5}{1.0223} = 4.8909.$$

Lastly the corresponding decrement of area between Y = 100 and Y = 95 is

$$\triangle \text{Area} = \frac{100 + 95}{2} \triangle X = 97.5 \cdot 4.8909 = 476.86$$

We have now derived the values for Col. IV to IX for Y = 100, and are ready for the second line where Y = 95. Value of area under curve beyond ordinate (Col. IV) is

$$A = 5000 - 476.86 = 4523.14$$

and starting with this value the figures for the other items in Line II are derived, one by one, as indicated above.

The solution is discontinued at $C/C_0 = 0.15$, and it might be imagined that the use of smaller increments of $\triangle Y$ would solve the gradient absolutely and reach $A = 0$ at $C/C_0 = 0$. However, this end point was reached by approaching the D_1 point from each side. Three trials are shown in Table III. Note that the change in C/C_0 is in

Table II — Computations for Ideal Gradient
See text for fundamental assumptions and derivations

Col. I $Y = 100 \frac{C}{C_0}$	Col. II Relative D_{C/C_0}	Col. III (Relative $D_{C/C_0})^{3/2}$	Col. IV A	Col. V $\frac{A}{C/C_0}$	Col. VI $\frac{A_1}{C/C_0}$	Col. VII Slope	Col. VIII $\triangle X$ (for $\triangle Y = 5$)	Col. IX $\triangle$ Area
100	1.2099	1.33084	5000	5000	3757	1.0223	4.8909	476.86
95	1.16957	1.26486	4523.14	4761.2	3764	1.0254	4.8761	451.04
90	1.12924	1.20000	4072.10	4524.5	3770	1.0280	4.8638	425.58
85	1.08891	1.13629	3646.52	4290.0	3775	1.0302	4.8534	400.41
80	1.04858	1.07375	3246.11	4057.6	3779	1.0320	4.8450	375.49
75	1.00825	1.01240	2870.62	3827.4	3781	1.0328	4.8412	350.99
70	0.96792	0.95227	2519.63	3599.5	3780	1.0324	4.8431	326.91
65	0.92759	0.89337	2192.72	3373.4	3776	1.0307	4.8511	303.19
60	0.88726	0.83575	1889.53	3149.2	3768	1.0271	4.8681	279.92
55	0.84693	0.77942	1609.61	2926.5	3755	1.0214	4.8952	257.00
50	0.80660	0.72442	1352.61	2705.2	3734	1.0120	4.9407	234.68
45	0.76627	0.67077	1117.93	2484.2	3703	0.9977	5.0115	212.99
40	0.72594	0.61852	904.94	2262.3	3658	0.9763	5.1213	192.05
35	0.68561	0.56770	712.89	2036.8	3588	0.9414	5.3112	172.61
30	0.64528	0.51835	540.28	1800.9	3474	0.8801	5.6811	156.23
25	0.60495	0.47052	384.05	1536.2	3265	0.7560	6.6137	148.81
20	0.56462	0.42426	235.24	1176.2	2770	0.4294	11.6441	203.77
15	0.52429	0.37963	31.47					
10	0.48396							
5	0.44363							
0	0.4033							

the fourth decimal place for the three trials shown. Yet trial No. 3, with the highest D values, depleted the area at too high a C/C_o value, while trial No. 1 with the lower D values shows a positive value for the area at $C/C_o = 0$. Thus trial No. 2 is accepted as the correct solution for a ratio of three.

Table III — Trials to Determine Correct Value of Z for $w/u = 3$

Trial No.	Relative D $C/C_o = 0$	Relative D $C/C_o = 1$	C/C_o Where D $C/C_o = D_1$
1	$u = 0.40323$	$w = 1.20969$	$Z = 0.73999$
2	$u = 0.40330$	$w = 1.20990$	$Z = 0.73977$
3	$u = 0.40334$	$w = 1.21002$	$Z = 0.73965$

By similar sequences of trial and error, conditions for two other ratios of diffusion rates at surface and core were obtained, and the data are compiled in Col. I to IV of Table IV. Note the significance of the first line (Ratio = 1). Under this supposition the value of Relative D_{C/C_o} is unity for all values of C/C_o, and the derived curve represents the D_1 gradient where the diffusion rate is independent of concentration. Since Table I is tabulated directly from tables of the probability integral, the construction of this gradient merely reverses the process by which the table was obtained.

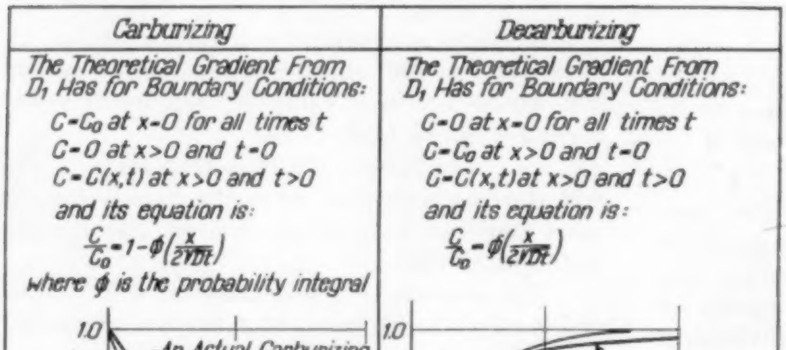


Fig. 4 — General Relation of Actual and Theoretical Carbon-Depth Curves D_1 (Plotted in Dimensionless Units) for Both Carburizing and Decarburizing Conditions

We might pause to interpret these new ratios of 2 and 4 in terms of Fig. 2 (right). It is remembered that ratio 2 means that the diffusion rate at the surface (where carbon is maximum) is assumed to be twice that which applies to the carbon content of the original bar (core carbon). On such an assumption, however, point E in Fig. 2 must be shifted slightly from its correct location for ratio 3, in order that all the other conditions be met, principal among which is that the area under the derived curve must be the same as that under the theoretical curve. The vertical ordinate Z of point E for a given ratio, deserves special attention, to be given shortly.

We will now attempt to correlate the values of w (Relative D_c at the surface where $C/C_o = 1$) and value of C/C_o where the diffusion rate equals the hypothetical diffusion rate of the D_1 gradient (that is, Z of Fig. 2, where $D_{C/C_o} = D_1$), under the various assumptions of ratio w/u given in the first column of Table IV. This correlation is shown in Col. V to VII of Table IV. It is seen that the arithmetical operations indicated at the head of these columns give results in Col. VII which are the same as those in Col. IV. We therefore write the following equations which are independent of the ratio w/u, or slope of the inclined lines in Fig. 2:

$$Z = (C/C_o \text{ where } D_{C/C_o} = D_1)$$
$$= 0.36795 \text{ (Relative } D_{C/C_o = 1})^{3/2} + 0.25000$$

Equation (2)

The above conclusion is applied in Fig. 4, in terms of the direction of flow of the solute, relative to the surface. To take this direction into consideration, equation (2) may be restated:

Table IV — Summary of Data for Four Values of Ratio w/u (Relative $D_{C/C_o=1}$ ÷ Relative $D_{C/C_o=0}$)

Col. I Ratio w/u	Col. II Relative D $C/C_o = 0$	Col. III Relative D $C/C_o = 1$	Col. IV C/C_o Where D $C/C_o = D_1$	Col. V $w^{3/2}$	Col. VI Col. V ×0.36795	Col. VII Col. VI +0.25000
1	$u = 1.0$	$w = 1.0$				
2	$u = 0.5835$	$w = 1.1670$	$Z = 0.7138$	1.26068	0.46387	0.7139
3	$u = 0.4033$	$w = 1.2099$	$Z = 0.7398$	1.33084	0.48968	0.7397
4	$u = 0.3073$	$w = 1.2292$	$Z = 0.7514$	1.36280	0.50144	0.7514

$Z = (C/C_o \text{ where } D_{C/C_o} = D_1)$
$= 0.36795\ (\text{Relative } D_{C/C_o} \text{ at Surface})^{3/2} + 0.25000$

Equation (3)

Specifically, for the carburizing gradient equation (3) now becomes: $Z = (C/C_o \text{ where } D_{C/C_o} = D_1)$

$$= 0.36795\ (D_{C/C_o = 1})^{3/2} + 0.25000$$

Equation (4)

or in the notation of Fig. 2:

$$Z = 0.36795\ w^{3/2} + 0.25000 \quad \text{(4a)}$$

Table V — Values of Z (Fig. 2) for Carburizing and Decarburizing Operations

Z	$\left(\text{Rel. } D_{C/C_o} \text{ at Surface}\right)^{3/2}$	w	u	w/u
	Carburizing Process			
0.770	1.41323	1.2593	0.13191	9.547
0.760	1.38606	1.2431	0.23019	5.400
0.750	1.35888	1.2268	0.31960	3.838
0.740	1.33170	1.2104	0.40116	3.017
0.730	1.30452	1.1939	0.47575	2.509
0.720	1.27734	1.1772	0.54434	2.162
0.710	1.25017	1.1605	0.60706	1.912
0.700	1.22299	1.1436	0.66494	1.720
0.690	1.19581	1.1266	0.71822	1.569
0.680	1.16864	1.1095	0.76732	1.446
0.670	1.14146	1.0922	0.81281	1.344
0.660	1.11428	1.0748	0.85480	1.257
0.650	1.08710	1.0572	0.89378	1.183
0.640	1.05993	1.0396	0.92960	1.118
0.630	1.03275	1.0217	0.96305	1.061
0.620	1.00557	1.0037	0.99396	1.010
	No Flow of Carbon			
0.61795	1.00000	1.0000	1.00000	1.000
	Decarburizing Action			
0.610	0.978394	1.0092	0.98554	1.024
0.600	0.951216	1.0219	0.96721	1.056
0.590	0.924038	1.0356	0.94870	1.092
0.580	0.896861	1.0507	0.93000	1.130
0.570	0.869683	1.0670	0.91112	1.171
0.560	0.842506	1.0848	0.89203	1.216
0.550	0.815328	1.1041	0.87275	1.265
0.540	0.788150	1.1251	0.85324	1.319
0.530	0.760973	1.1476	0.83352	1.377
0.520	0.733795	1.1721	0.81355	1.441
0.510	0.706618	1.1986	0.79334	1.511
0.500	0.679440	1.2271	0.77286	1.588
0.490	0.652262	1.2580	0.75211	1.673
0.480	0.625084	1.2913	0.73107	1.766
0.470	0.597907	1.3273	0.70973	1.870
0.460	0.570730	1.3662	0.68805	1.986
0.450	0.543552	1.4082	0.66603	2.114
0.440	0.516374	1.4530	0.64364	2.257
0.430	0.489197	1.5026	0.62086	2.420
0.420	0.462019	1.5556	0.59764	2.603
0.410	0.434842	1.6130	0.57387	2.810
0.400	0.407664	1.6753	0.54980	3.047
0.390	0.380486	1.7428	0.52508	3.319
0.380	0.353309	1.8162	0.49978	3.634
0.370	0.326131	1.8960	0.47380	4.002
0.360	0.298954	1.9829	0.44710	4.435
0.350	0.271776	2.0778	0.41958	4.952

For the decarburizing gradient we may write, in place of equation (3):

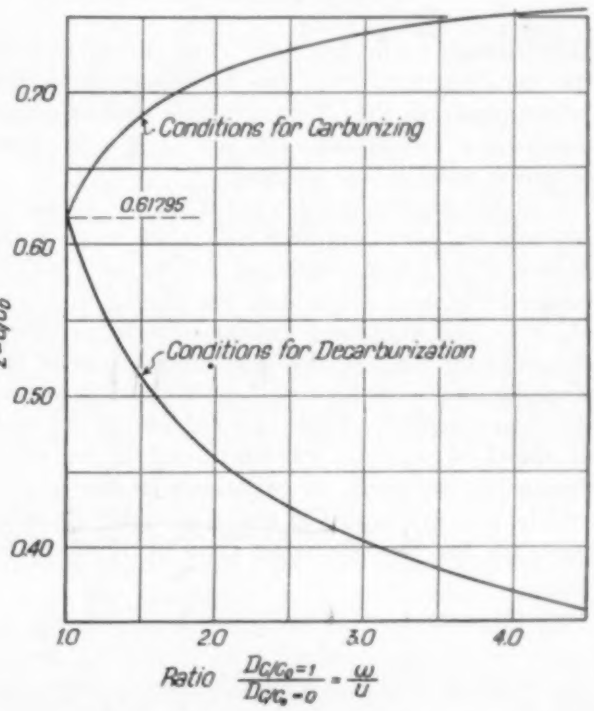
$$Z = (C/C_o \text{ where } D_{C/C_o} = D_1)$$
$$= 0.36795\ (D_{C/C_o = 0})^{3/2} + 0.25000$$

Equation (5)

$$\text{or } Z = 0.36795\ u^{3/2} + 0.25000 \quad \text{(5a)}$$

Figure 2 shows that a small change in Z will make relatively large changes in w (Relative $D_{C/C_o = 1}$) and in u (Relative $D_{C/C_o = 0}$) together with the ratio w/u. Computations similar to those leading up to Table II to IV have been made to establish these relationships for values of Z between 0.350 and 0.770, and these are assembled in Table V and plotted in Fig. 5.

Fig. 5 — Graphical Representation of Relations Between z and w/u



Part II. Experimental Data and Discussion

Before attempting to apply the mathematical development of Part I to experimental data, it will be necessary to apply a test of boundary conditions to the carburizing and decarburizing processes. The mathematical derivations postulate that the surface carbon concentration is held constant throughout the duration of any test run.

Two tests were made at 1700° F., with four test pieces for both the carburizing and the decarburizing runs. In both tests, a bar is removed at approximately 2, 4, 6 and 8 hr., after stable surface conditions were thought to have been attained. Temperature was chosen at 1700° F.,

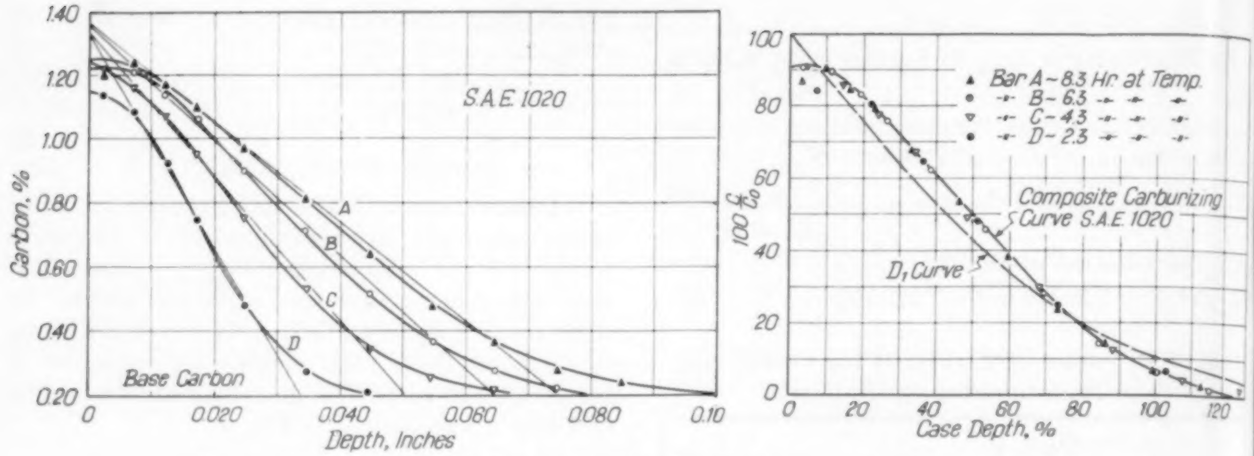


Fig. 6 (Left) — Actual Carbon-Depth Gradients on 1-In. Bars of S.A.E. Steel Carburized in Gas for Various Times at 1700° F. Right is a composite curve of all experimental points plotted in standard dimensionless units

high enough to insure 0.0% C at the surface in the decarburizing run; the ferrite band in the micrographs in Fig. 7 gives ample evidence that boundary conditions (C = 0 at $X = 0$) were obtained early in the process.

Concentration-depth curves for the carburizing run on 1-in. bars of S.A.E. 1020 steel, withdrawn after 2.3, 4.3, 6.3 and 8.3 hr. at 1700° F. respectively, and air cooled, are shown in Fig. 6 at left. As explained in the article in *Metal Progress* for August 1943 the intersection of the straight line with base carbon horizontal marks the "case depth". Experimental points on each of these curves are recomputed in terms of dimensionless units, as explained in the former article, and assembled in Fig. 6 at right. Similar plots for the decarburizing runs at 1700° F. on 0.93% C steel for 2.3, 4.3, 6.3 and 8.3 hr. are shown in Fig. 8. The range of data points for the composite curves demonstrates the accuracy with which boundary conditions are held, and no further comment need be made.

Before submitting additional test data, a standard of comparison is now developed from the single carburizing test run shown in the "Analysis of a Typical Carburizing Gradient" published in *Metal Progress* for June 1944. Figure 9 is a graph showing actual diffusion rates versus carbon contents, taken from Table II in that article. (It is really the same thing as Fig. 4 of the June article, with coordinates changed.) The equation of the line in Fig. 9 is

$$10^6 \cdot D_c \text{ (in.}^2\text{/hr. @ 1700° F.)} = 32.3\,(1 + 2.7 \cdot \%\ \text{C}) \qquad (6)$$

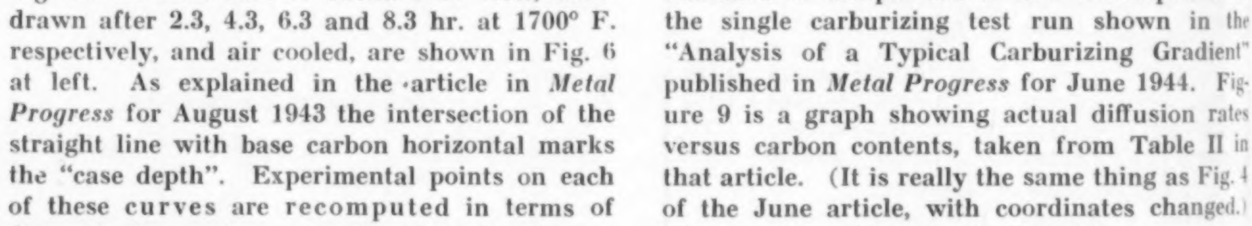


Fig. 7 — Edge Sections, at 100 and 750 Diameters, From a 0.93% C Bar Decarburized 2.3 Hr. in Test Run at 1700° F. Nital etch

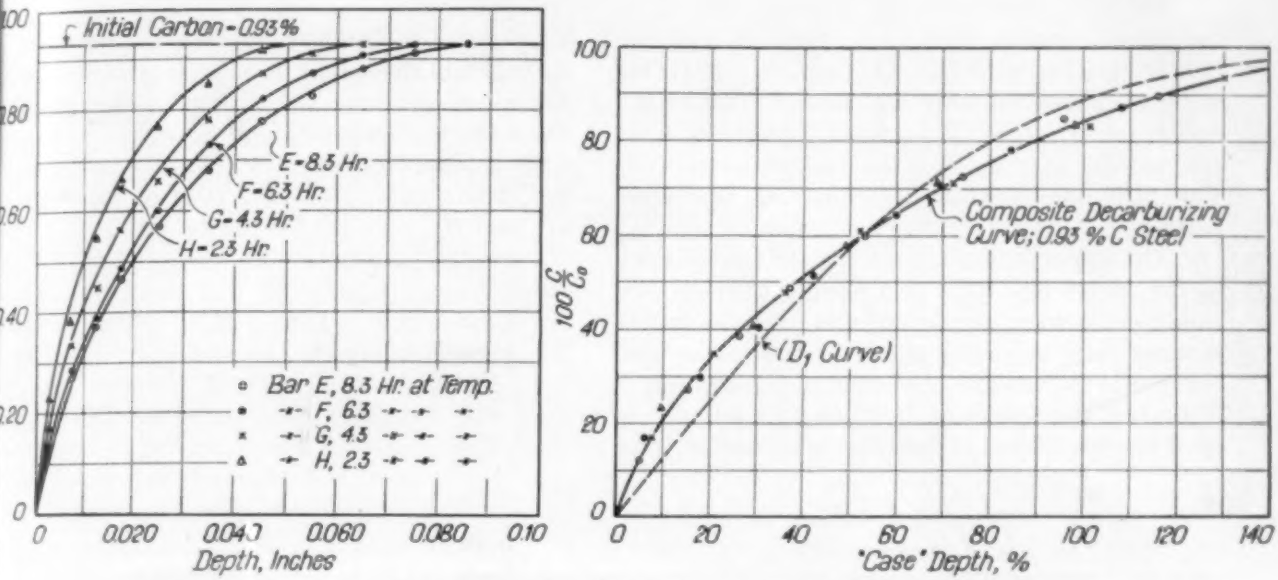


Fig. 8 (Left) — Actual Carbon-Depth Gradients on 1-In. Bars of 0.93% Carbon Steel, Decarburized Various Times at 1700° F. Right is a composite curve of all experimental points plotted in standard dimensionless units

Decarburization

Decarburizing data will now be presented data analyzed by the above formulation, with the aid of Table V, page 493, derived in Part I.

Three steels are chosen for the experimental run, and their analysis covers a wide range in carbon content — 0.45, 0.90 and 1.24%. Note that the highest analysis is close to, but below that of saturated austenite at 1700° F. (1.34% C.). Thus there should be no excess cementite and a problem of changing phase boundary conditions. The concentration-depth curves are shown in Fig. 10, while the computations for carbon loss (analogous to "added carbon" in a carburizing experiment) are contained in Table VI. Bar size was 1¼ in. diameter by 6 in. long; turnings near the end were rejected from the analytical sample. Each negative item in the columns "Added" in Table VI is the depth of cut times difference in original carbon and analysis of cut, times the factor 4 (to bring it to the amount of carbon in pounds added to 10 sq.ft. of surface area, which is the definition for "Added Carbon" given in *Metal Progress*, August 1943, page 270).

The log sheet of the experiment showed the furnace at 1700° F. throughout, and a constant flow of 55 cu.ft. per hr. of the generator gas used in former experiments. At 8:20 steam at 3.0 psi. pressure was introduced into the furnace, whose atmosphere was maintained at a pressure of 1.4 to 1.6 in. of water. By 8:50 the atmospheric conditions had reached stability with 4.2% CO_2 in

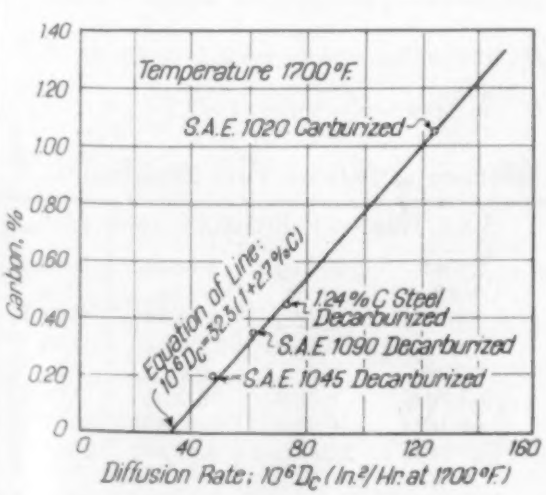


Fig. 9 — Diffusion Rates for Various Carbon Contents, According to Work on S.A.E. 1020 Reported in June Issue, and Three Points for the Steels Reported in Table VII

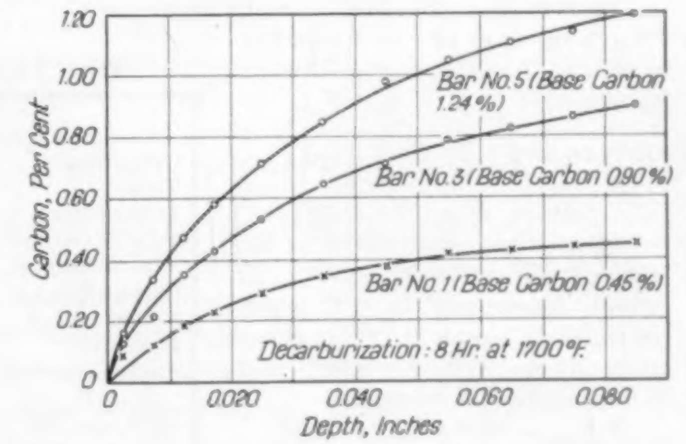


Fig. 10 — Carbon-Depth Gradients of Plain Steels of Various Carbon Content; Decarburized 8 Hr. at 1700° F.

the effluent, and the bars were charged. Amount of CO_2 gradually increased to 5.1% at 11:30, when the steam pressure was lowered to 2.5 psi., and again to 2.0 psi. at 1:15. CO_2 gradually lowered to 4.5% at 5:20, when the bars were removed. This atmosphere, while decarburizing, was non-scaling.

The application of the solution development to the above test data is a simple matter. An equation showing the significance of D_1 (a hypothetical rate, independent of concentration, that transports an amount of carbon in t hours equal to that of the actual or D_c gradient) was developed for the typical carburizing gradient analysis and is copied here from page 1112 of the June issue:

Table VI — Carbon Transport in Bars Decarburized 8 Hr. at 1700° F.

Depth of Cut, Inches	Bar No. 1 Base C = 0.45%		Bar No. 3 Base C = 0.90%		Bar No. 5 Base C = 1.24%	
	% C	Added	% C	Added	% C	Added
0.005	0.09	−0.0072	0.13	−0.0154	0.16	−0.0216
0.010	0.12	−0.0066	0.22	−0.0136	0.34	−0.0180
0.015	0.19	−0.0052	0.35	−0.0110	0.47	−0.0154
0.020	0.23	−0.0044	0.43	−0.0094	0.58	−0.0132
0.030	0.29	−0.0064	0.54	−0.0144	0.71	−0.0212
0.040	0.35	−0.0040	0.64	−0.0104	0.84	−0.0160
0.050	0.37	−0.0032	0.71	−0.0076	0.98	−0.0104
0.060	0.42	−0.0012	0.79	−0.0044	1.05	−0.0076
0.070	0.43	−0.0008	0.83	−0.0028	1.10	−0.0056
0.080	0.44	−0.0004	0.86	−0.0016	1.14	−0.0040
0.090	0.45	.....	0.90	.....	1.20	−0.0016
0.100	0.45	.....	0.90	.....	1.22	−0.0008
Totals:		−0.0398		−0.0906		−0.1354

$$10^6 \cdot D_1 \text{ (in.}^2\text{/hr.)} = \left(\frac{\text{Added Carbon}}{\text{Carbon Spread}}\right)^2 \div 20.4\, t \tag{7}$$

From Table VI we note that "Added Carbon" is —0.0906 (negative, for it is really carbon loss); "Carbon Spread" is 0.90-0.0 = 0.90 and $t = 8$ hr. Substituting in equation (7):

$$10^6 \cdot D_1 = \left(\frac{-0.0906}{0.90}\right)^2 \div 20.4 \times 8$$

Solving, $D_1 = 62.0 \times 10^{-6}$

But D_1 is also related to D_c, through the ratio $D_{c(\max.)}/D_{c(\min.)}$, which determines the C/C_o point at which D_1 equals D_c. From equation (6) we write for 0.90% and 0.00% carbon respectively,

$$10^6 D_{0.90} = 32.3\ (1 + 2.7 \cdot 0.90)$$
$$10^6 D_{0.0} = 32.3$$

and the ratio between the two is 3.430 to 1. Turning to Table V or equation (we find that the ratio 3.43 to 1 for decarburizatio has a complementary Z or C/C_o value of 0.38 Then the carbon content at which $D_c = D_1$ is 0.386 x 0.90%, or at 0.35% C. Thus from th decarburizing test on 1090 steel at 1700° F., w say that $D_{c=0.35} = 62.0 \times 10^{-6}$ in. ²/hr.

Similar computations were made for th other bars carburized in this same run. Dat are summarized in Table VII, to which a colum is added covering the experiment published i the June issue. The derived diffusion rates fo the percentage of carbon where $D_c = D_1$ ar plotted as points on Fig. 9, and it is found tha they fall satisfactorily close to th straight line.

Conclusion

Any new method of analysi must be subjected to rigorous test to prove its adaptability to the proc ess in question; for this reason, w have spared no efforts in checking these results, and no words in th attempted development. We ar inclined to extend this tabulation to a lower temperature range, where a series of tests indicated that tem perature does not change the varia tion of D. Thus we tabulate:

°F.	$D_c \times 10^6$ In.²/Hr.
1700	32.3 (1 + 2.7 · % C)
1650	23.0 (1 + 2.7 · % C)
1600	16.2 (1 + 2.7 · % C)

We also suggest that the formulation fo diffusion of carbon in gamma iron is very close to the following expressions, where T = 460 + °F

$$D_c, \text{ in.}^2 \text{ per hr.} = 51.6\ (1 + 2.7 \cdot \%\ C)\ 10^{-\frac{13400}{T}}$$

$$D_c, \text{ cm.}^2 \text{ per sec.} = 0.092\ (1 + 2.7 \cdot \%\ C)^{-\frac{13400}{T}}$$

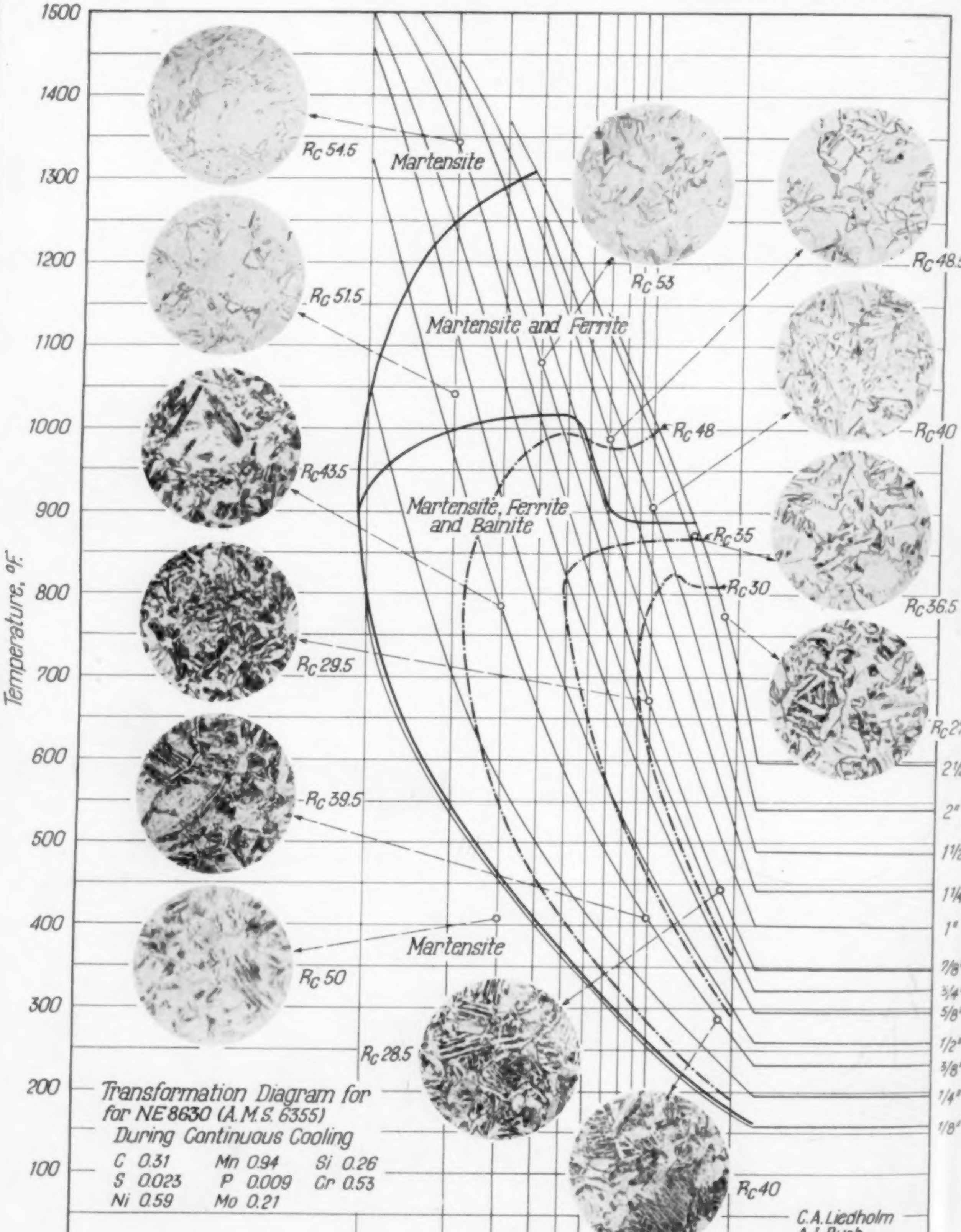
Table VII — Summary of Data for Four Experiments

	S.A.E. 1020	S.A.E. 1045	S.A.E. 1090	1.24% C
Operation	Carb.	Decarb.	Decarb.	Decarb.
Time	8 hr.	8 hr.	8 hr.	8 hr.
Temperature	1700° F.	1700° F.	1700° F.	1700° F.
Max. % Carbon	1.34	0.45	0.90	1.24
Min. % Carbon	0.20	0.0	0.0	0.0
Carbon spread	1.14%	0.45%	0.90%	1.24%
Added carbon	+0.1624	−0.0398	−0.0906	−0.1354
D_c ratio	3.078 to 1	2.215 to 1	3.43 to 1	4.348 to 1
% Carbon where $D_c = D_1$	1.05	0.20	0.35	0.45
$10^6 D_1$ (in.²/hr.)				
From Equation (7)	124	47.9	62.0	73.0
From Equation (6)	123.9	49.7	62.8	71.5

Transformation of NE 8630
During Continuous Cooling

By C. A. Liedholm and Associates, Curtiss-Wright Corp.

See *Metal Progress*, Jan. 1944, p. 94



Photomicrographs at 500 diameters

Jet Propulsion—

the principles and the metallurgy involved

JET propulsion, rocket shells, "bazookas", robot bombs, and gas turbines are all in the newspapers and popular magazines these days. Divergent though they seem, they all stem from a single physical principle long known, but are applications only recently studied intently and developed. The gas turbine — possibly better called a turbo-motor — is first cousin to a steam turbine, wherein the flywheel energy is secured, not from the action of expanding (and cooling) steam upon vanes at the rim of a wheel, but from a mixture of hot and compressed gases, principally air. In jet propulsion the intervention of such a turbo-motor and a propeller is dispensed with (but not the air compressor), the "shove" being the simple reaction equal and opposite to the hot exhaust. Robot bombs utilize such a simplified "power plant", into which the necessary air for combustion is rammed at high speeds and supplemented by exhaust from storage in compressed air cylinders. Rocket artillery shells and bazookas also are propelled by hot exhausts, but both fuel and the oxygen for their combustion are contained in solid chemicals, semi-explosive in nature.

Perhaps the very newsworthy nature of this general subject would be a warrant for a discussion in *Metal Progress*, but there is added reason in that the practicability of the turbo-motor operated by hot gas has awaited the metallurgists' ability to produce a workable and not too expensive alloy capable of operating under stress at temperatures approaching a red heat.*

Articles on jet propulsion intended for popular reading always start out with a reference to a spinning lawn sprinkler. (A helicopter model, steam jet propelled, actually flew for half a mile in Paris in 1842!) The lawn sprinkler is a good illustration of Newton's third law of motion, which is the physical principle involved in both. Action and its equal reaction also come into play when firemen play a hose on a fire — two or three men have to lean against the nozzle else it will tear itself out of grip and thrash around the ground like an angry snake. Since Newton's law applies alike to solids and fluids (water, steam, hot gas), and since simple devices for jet propulsion of ships have been operated, it is handy to start this account with a description of them.

Jet Propulsion of Steamships

In 1866, when screw propulsion was being developed, the British admiralty built three ships, all of 1160 tons, two fitted with twin screws and the third (the "Waterwitch") equipped with Ruthven's system, patented 17 years earlier. As shown in Fig. 1, the power plant comprised a centrifugal pump drawing water from underneath the boat and discharging it overboard at either

*EDITOR'S NOTE — As has frequently happened in the past, the American public has been so well protected by the censoring authorities that news about this wartime development comes largely from our British cousins. Principal sources of the information in this article are as follows:

"History of Jet Propulsion", unsigned articles in *The Engineer*, Jan. 21, 28, Feb. 4, 1944.

"The Future of the Gas Turbine", by B. Wood, *The Engineer*, March 17, 24, 31, 1944.

"The Basic Gas Turbine Plant and Some of Its Variants", by J. Kenneth Salisbury, *General Electric Review*, May 1944.

"Gas Turbines and Jet Propulsion Power Plant"; extracts from 32nd Wilbur Wright Memorial Lecture by A. H. Roy Fedden, before the Royal Aeronautical Society. Extracts in *The Engineer*, June 2 and 9, 1944.

"Gas Turbines and Jet Propulsion for Aircraft" (book), by G. Geoffrey Smith, Flight Publishing Co., Ltd., London, England.

"The Pilotless Aircraft", a release from the British Air Ministry News Service.

"Jet Propulsion; From Fancy to Fact", by Willy Ley, *Aviation*, Jan. and Feb. 1944.

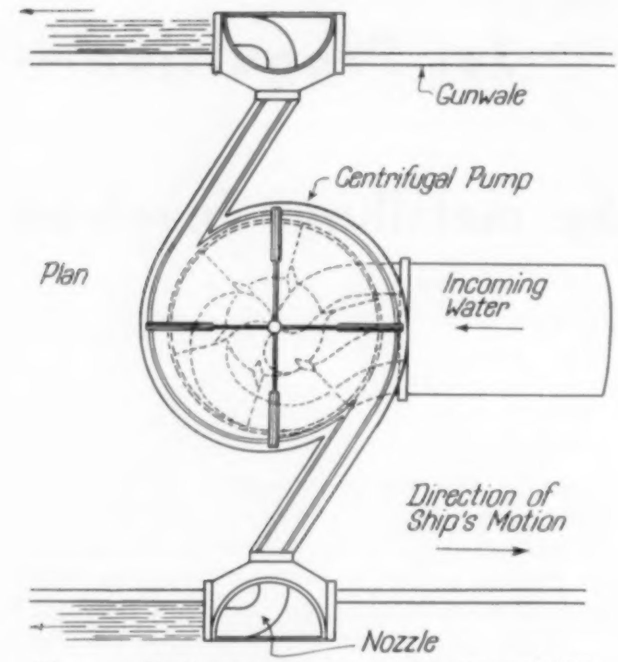


Fig. 1 — Ruthven's System of Jet Propulsion for Steamships; 1866 (From The Engineer)

side. (The nozzles could be turned about if it were necessary to move astern.) In extensive trials the "Waterwitch" attained 9.3 knots with 760 hp.; the twin-screw vessels made 9.6 knots with 696 hp. Similar trials in Sweden shortly thereafter gave a similar advantage to screw propulsion of 10-ton torpedo boats. The problem then lay dormant until 1881, when the English again tried the scheme on small torpedo boats. The pumps were improved, but the competing screws also were improved, and the result of this trial was that the over-all efficiency of the engine, screw shaft and propeller was almost exactly double that of the engine, pump and jet. So the matter rested.

During World War I interest again was aroused and numerous sub-chasers were so equipped, primarily because their operation was much more silent than the conventional power plants, and the craft could come quite close before being audible to the submarine's listening devices. Some small boats were exhibited and demonstrated to motor-boating enthusiasts in 1920, equipped with the so-called Hotchkiss pump, diagrammed in Fig. 2. It is obvious that this is merely a paddle wheel placed in a casing *within* the ship's hull. It should also be obvious that impellers or paddle wheels are not necessary to project a craft through a fluid medium — say air — if a moving column of the fluid can be otherwise created — as the exhaust of burned fuel. But that is getting ahead of the story.

Now wherein lies the demonstrated advantage of putting the screw or paddle wheel of a ship outside the hull instead of inside? In the latter scheme there must be some loss of energy in friction between water and ducts, both incoming and outgoing. That means that the most efficient system of jet propulsion must have the shortest and least contorted conduits. The limit is reached in zero length, which is the same as saying that, for a steamship, the propeller should be outside the hull. On the other hand, the inside propeller has some possibility of advantages. The conventional screw propeller loses efficiency due to cavitation effects, and also uses up some energy uselessly in rotating the rearward stream of water. Theoretically, at least, the designer of an enclosed impeller may be able to correct both of these wastes.

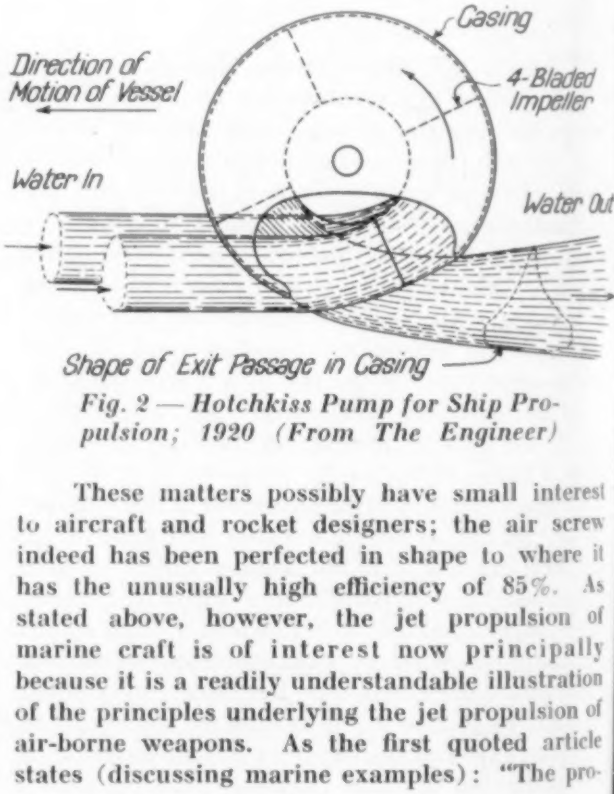


Fig. 2 — Hotchkiss Pump for Ship Propulsion; 1920 (From The Engineer)

These matters possibly have small interest to aircraft and rocket designers; the air screw indeed has been perfected in shape to where it has the unusually high efficiency of 85%. As stated above, however, the jet propulsion of marine craft is of interest now principally because it is a readily understandable illustration of the principles underlying the jet propulsion of air-borne weapons. As the first quoted article states (discussing marine examples): "The pro-

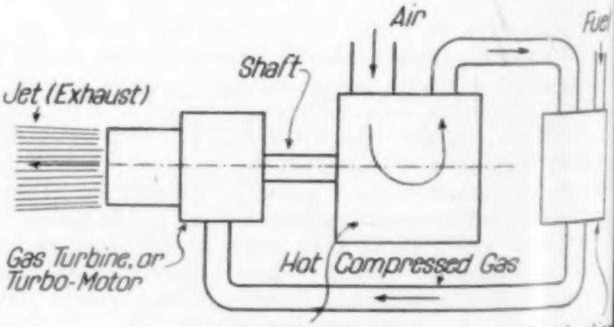
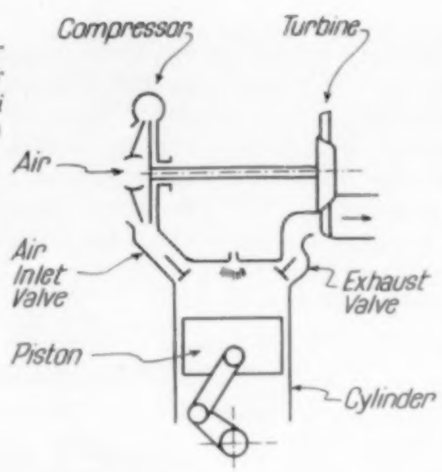


Fig. 3 — Generalized Diagram of Power Plant for Jet Propulsion of Aircraft (From The Engineer)

Fig. 4 — Diagram of the Turbo-Motor and Compressor Used for Diesel Engine Feed in the Büchi Process (From The Engineer)



pelling force is the reaction of the jet issuing from the orifice, and this reaction is the same whether the orifice is above or below the water in which the vessel is floating. The magnitude of the reaction depends only upon the mass flow and velocity of the jet and the speed of the vessel.* The propulsive force is not in any way determined by the pressure of the jet impinging against the relatively immobile, 'solid' water at the stern of the ship. The same remarks apply to the case of the jet-propelled aircraft. In the ship the discharge of the jet below the water surface or above it is equivalent in the aircraft to flying at ground level or at a height at which the density of the air is very low. The reaction of the jet in the aircraft would not be affected by the change in the density of the surrounding air, all other factors remaining unaltered."

Aircraft Applications in General

Consider now, broadly, the application of jet propulsion to aircraft. There would be no reason why a hydraulic system entirely analogous to Ruthven's or Hotchkiss's could not be applied, wherein air would be taken into an engine-driven compressor, compressed, and discharged through a rearward pointing orifice. Such an arrangement would suffer unduly from energy losses in the engine-compressor unit, and the ideas of numerous inventors have therefore turned to some adaptation of the system sketched in Fig. 3, where the fuel is burned not in a reciprocating engine but in a combustion chamber, thus providing a gas of high energy content. Since aircraft is to operate at high altitudes, an air pump (corresponding to a supercharger on a reciprocating gas engine) is necessary to provide the requisite amount of oxygen at all times for rapid combustion. To drive this pump, what would be better than an impulse wheel (turbo-motor) getting its energy from the hot gas as it flows from combustion chamber to exhaust orifice? The rotary air compressor or turbo-blower required in such a combination is already at hand, highly developed in the form of aircraft engine superchargers. The gas turbine or turbo-motor is not so simple, and obviously requires metal that can withstand simultaneously the stress associated with rotation at high speeds and corrosion or scour of hot gas. Its rudimentary

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*According to Newton's third law of motion the force exerted by the jet on the craft is equal to the change of momentum of the fluid leaving the orifice. If V is the speed of the craft (relative to still water or air), V_1 the speed of the fluid in the jet relative to the craft, $v = V_1 - V$ the speed of the fluid in the jet relative to still water or air, A the area of the orifice, and ρ the mass of a cubic foot of the fluid in the jet, then the volume of fluid delivered astern per second will be AV_1 and its mass ρAV_1. Its momentum (mass times velocity) will therefore be $\rho AV_1(V_1-V)$, which is also the reaction R exerted on the craft. The useful work of propulsion done in one second is RV or $\rho AV_1(V_1-V)V$, while the energy in the discharged jet (½ its mass times its velocity squared) is $\frac{1}{2}\rho AV_1(V_1-V)^2$. The total work absorbed by the fluid in the propulsion system equals the useful work done in moving the craft, or $\rho AV_1(V_1-V)V$, plus the energy remaining in the jet after its discharge, or $\frac{1}{2}\rho AV_1(V_1-V)^2$, which comes out to $\frac{1}{2}\rho AV_1(V_1^2-V^2)$. The "efficiency" of the jet is the ratio of the useful work to the total work, or (simplifying)

$$\text{Jet efficiency} = \frac{2V}{V_1 + V}$$

Interpreting this last expression, jet efficiency of 100% is had if the speed of the jet relative to the craft is equal to the speed of the craft relative to still air. However, if the value $V_1 = V$ then the reaction R exerted on the craft is also zero. Useful work is done (R is positive) only when the velocity of the jet V_1 is *greater* than the velocity of the craft. If, say, it is three times as great, the efficiency of the jet is 50%—that is to say, half its energy is used in propelling the ship and half remains in the jet after its discharge. In this circumstance the jet's absolute velocity v is twice the absolute velocity of the craft. While these expressions represent the theoretical maximum, and would be modified if frictional losses in intake and exhaust are allowed for, it should be obvious that they apply to a fluid like hot exhaust gases as well as to water.

It is worthy of emphasis that the thermal efficiency of the flame may be very high, but the jet efficiency (due to slow speed of the craft) may be very low. For example, at the beginning of a jet propelled flight V is hardly more than zero and the jet efficiency as given by the equation above also is very low. The equation also shows that the jet efficiency increases as the speed of the craft approaches the speed of the jet. What this implies may be imagined from the statement that the jet from best fireworks (rockets) is on the order of 1500 m. per hr. and from liquid fuel jet-motors is three times as high. The conclusion that jet propelled aircraft must be *very* fast is inescapable.

form was already well known, however, in the Büchi pressure charging sets for four-cycle diesel engines, widely used on the Continent (Fig. 4). In this device the gas turbine operates (as it does on the modern air engine supercharger perfected by General Electric Co.) on the exhaust from a reciprocating gas engine whose temperature is comparatively low. It may be interesting to observe that in this embodiment the "gas turbine" is an *auxiliary* to the main power-generating unit, recuperating some of the waste energy, whereas the modern view of a gas turbine is that it itself should be the prime mover.

Gas Turbine for Power Generation

Let us now turn to the gas turbine in its modern form as a producer of power — as a prime mover, so to speak, in distinction from its use as an auxiliary in Büchi diesels or in aircraft engine superchargers. Figure 5 is a diagram of such a plant, and Fig. 6 is a photograph of a cut-away model of a 3000-hp. gas-turbine power plant for marine vessel propulsion. In the latter photograph a series of combustion chambers are arranged around the right hand end of the main axis, and discharge hot gases against the vanes on the rim of the main impulse wheel. Corresponding elements in Fig. 3, 5 and 6 are easily recognized; if such a power plant as Fig. 5 or 6 were installed in an aircraft the electric generator or reduction gear for main drive shaft, not shown in the model but attached to the left end of the unit, would be replaced by an air screw (propeller).

Such plants did not develop overnight. They were proposed and built almost as soon as steam turbines appeared, but unfortunately most of these early machines gave no power — sometimes not enough to overcome their own friction and move! In this country the General Electric Co. has worked on the problem for 40 years, as early as 1904 operating small turbines at both Lynn and Schenectady. Abroad the important Swiss firm of Brown, Boveri & Co. was equally pertinacious, and more fruitful in concrete results. Reported installations by Brown, Boveri include about 25 units ranging up to 2000-kw. output to

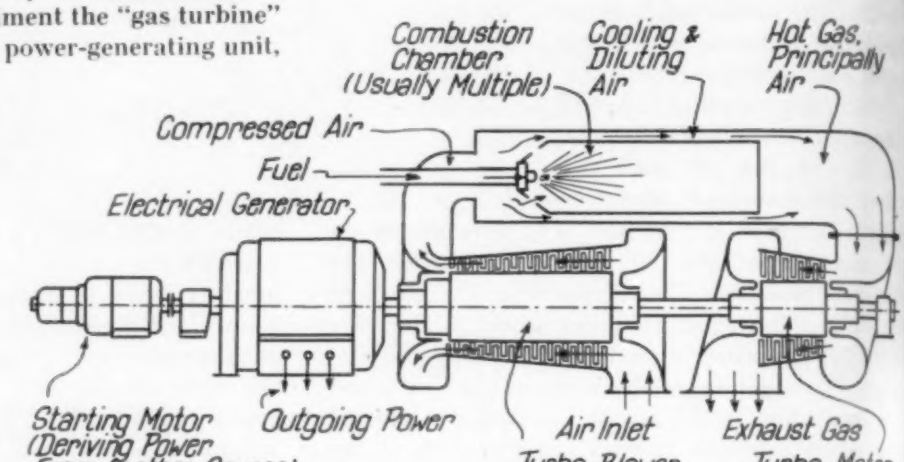


Fig. 5 — Diagram of the Modern Gas Turbine, Used as a Prime Mover for an Electrical Generator (From The Engineer). Actually the machine has multiple combustion chambers, rather than one large one

recuperate some of the energy of waste gases in the Houdry petroleum cracking process, three sizable units for blast furnace blowers, one 2200-hp. locomotive, and — just before the present war — a 4000-kw. oil-fired unit installed in bomb-proof quarters at Neuchâtel, Switzerland, for emergency electrical supply and peak loads on the normal network. Sponsors of this plant make much of its quick starting ability, small space requirements, and independence from water supply.

Since two-thirds of the entire power generated by the turbo-motor is required to drive its auxiliary air compressor, it is obvious that success depends on the greatest refinement in design of the latter. In fact, that appears to be a main contribution by General Electric Co. to the development; Sanford A. Moss of that firm has done a great deal of work since 1910 on centrifugal air compressors, it gradually becoming apparent that the centrifugal machine

> ***Jet propulsion, rocket projectiles, "bazookas", robot bombs and gas turbines are all linked together in the common use of white hot air or other gas as a source of energy. A review of information on these wartime developments already released by the censor will emphasize that all these devices depend on special alloys, reasonably cheap and workable, that can resist the stresses and scour imposed by the propellant for a useful time.***

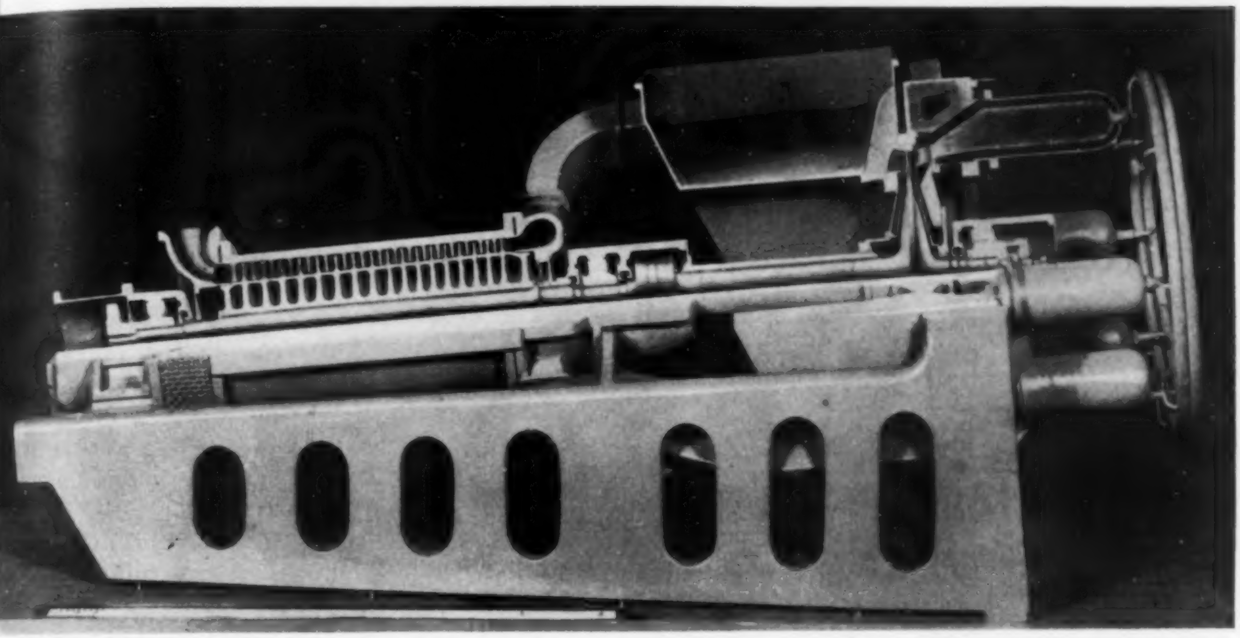


Fig. 6 — General Electric's Model of a 3000-Hp. Power Plant for a Steamship. The turbo-motor has a single impulse wheel rather than multiple, as diagrammed in Fig. 5

was considerably less efficient than the axial-flow machine of the Brown, Boveri Co., operating in reverse English, so to speak, from a multi-stage steam turbine. Such a compressor (4-stage) is shown in Fig. 7, and, as remarked, this preliminary work and the recent intensive work of aerodynamical experts have presented the designer of the gas turbine with one of his absolute essentials — a high speed, light-weight, rotary air compressor of high efficiency.

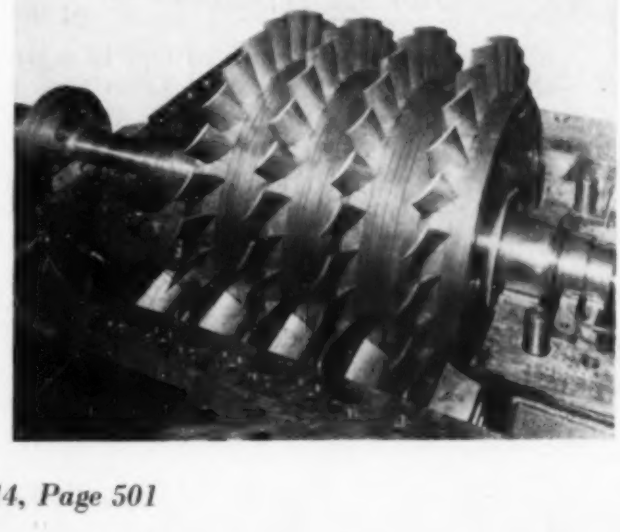
A good centrifugal compressor has a mechanical efficiency of about 65%, whereas modern axial flow compressors reach 85%. In compressing ordinary air to, say, five times its atmospheric pressure, the temperature increases from 70 to 425° F., so it is apparent that the construction of this end of the machine requires no unknown metal of special heat or corrosion resistance.

What this improvement in mechanical efficiency means may be gathered from the fact that with the older type turbo-motor and compressor having 65% efficiency, it was necessary to heat gases to 1100° F. at the turbine before the machine would even move (zero power output). Increasing the pressure from two atmospheres to four atmospheres did no good; the turbine throttle temperature for zero power output jumps up to 1425° F., beyond the capability of the metals then known. On the other hand, if the elements operate at 85% efficiency, a turbine starts to deliver power with compressed air at 2 atmospheres heated to only 450° F., obviously becoming available for use as a super-charging unit using relatively cool exhaust gas and rotor metals of non-critical properties.

High Temperature Essential

As Mr. Salisbury points out in his article in *General Electric Review,* the useful work obtainable from the gas turbine increases very rapidly as the compressor inlet temperature is decreased (as the aircraft goes to higher and higher altitudes) and as the turbine initial temperature is increased. Before the latter could be done, however, metallurgists have had to develop high strength creep resistant steel that can operate at 1100° F., at least. As the gas temperature goes

Fig. 7 — A Four-Stage Axial Flow Air Compressor, With Top Casing Removed, Showing Vanes on Rotor (From General Electric Review)



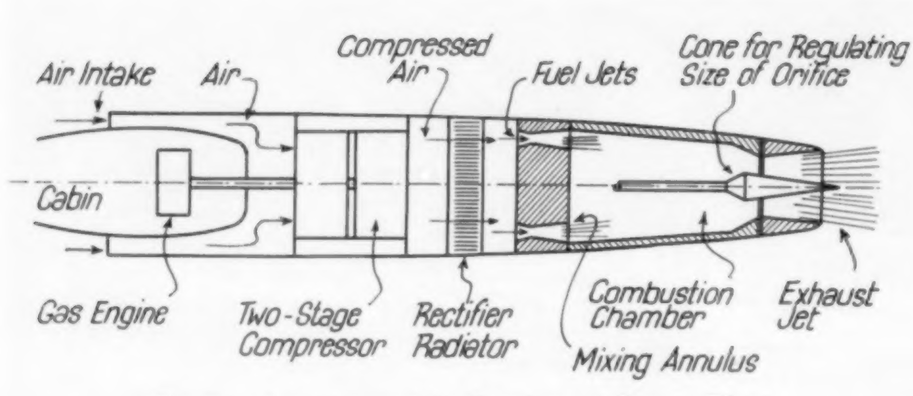


Fig. 8 — Arrangement in Fuselage of Power Plant in Italian Jet-Propelled Aircraft (From Flight)

up the amount of air that needs be handled is progressively smaller, so that we have a startling transformation of bulky machinery producing but little useful energy to power plants that are extremely compact, light in weight, and of reasonable over-all efficiency (about 18%, approximately half that of the most advanced steam cycles and diesel engines).

Further quoting Mr. Salisbury's article: "The General Electric Co. has chosen a single-stage turbo-motor of the impulse type which, although admittedly somewhat lower in efficiency than a multi-stage turbine, has the compensating advantage of permitting higher initial turbine temperatures. The expansion through the turbine occurs in a single step, and this results in a large drop in temperature before the hot gases come in contact with the buckets. The only parts which are subjected to the maximum temperature of 1600° F. are those which are stationary and which have relatively low stresses. The most highly stressed part of the machine, namely the wheel and its buckets, is subjected to a much lower temperature when a single stage is used."

Jet-Propelled Aircraft

It has already been indicated that in a jet-propelled aircraft the aim would be to have a turbo-motor just powerful enough to drive the turbo-blower, and the hot exhaust from the motor would then be available for jet propulsion, as diagrammed in Fig. 3. The only description which so far has appeared in print of such an aeronautical application is of an airplane designed in 1932 by Campini, an Italian, constructed by the Caproni Co., and flown in 1940. It had a pressure cabin for high altitude flight, and it weighed about 8800 lb. A diagram of the 1932 design is shown in Fig. 8. Its correspondence to the elements shown in Fig. 3 needs no discussion. The use of the "rectifier radiator" is not clear; apparently the propulsion devices in this aircraft occupied almost all of the fuselage. Late in 1941 a second and somewhat heavier design, the "C.C.-2" flew from Milan to Rome (170 miles) in 2 hr. 20 min. including a refueling stop. Its maximum speed was only 130 miles per hr.

A similar arrangement is believed to be the basis of one of the systems studied by the

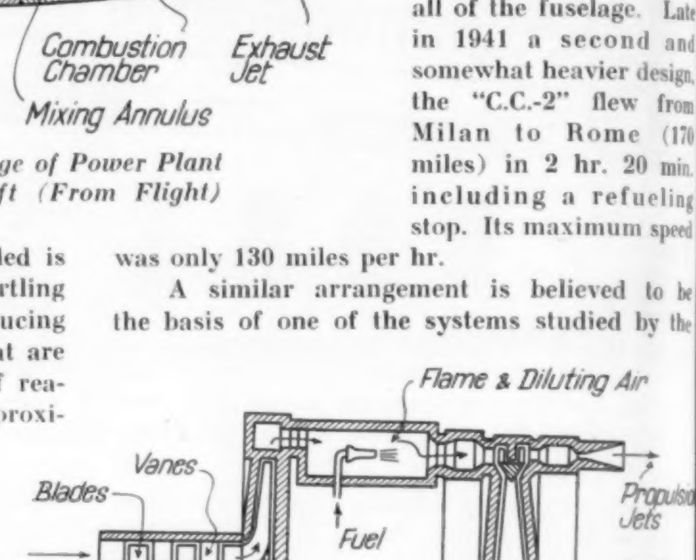


Fig. 9 — Jet Propulsion Power Unit (Fedden)

Junkers Co. in Germany. Although some ideas may be gleaned from enemy patent literature, nothing definite about their actual designs has so far appeared in the technical press.

The same might also be said of work done by the Allied governments. It is known that serious work on the application of gas turbines to aircraft propulsion commenced in England in the Royal Aircraft Establishment in 1928. Despite enthusiastic and successful work under the direction of Frank Whittle, it was not strongly backed by other governmental agencies until 1937. An interchange of information between the Allied governments, as well as between the associated British Thomson-Houston Co. Ltd. and General Electric Co. in America has led to the production in both countries of numerous jet-propelled aircraft which have undergone rigorous flight tests since May 1941,

thus antedating the Italian flight mentioned above, and have since been so rapidly perfected that they doubtless have now been in combat.

While the exact form of the present power plant is still secret, a drawing from Sir Roy Fedden's lecture illustrates its utmost simplicity (Fig. 9). It is understood of course, that only a small part of the compressed air is necessary to burn the required fuel; the remainder is necessary to cool the products of combustion down to where they will not destroy rapidly the blades and vanes on the turbo-motor. The unit is started by an electric motor; once air is being compressed the fuel is turned on and ignited, the unit picks up speed, and the starter is disconnected. A curve sheet (Fig. 10) from the same lecture indicates the estimated propulsive characteristics of rocket, jet and propeller at various speeds of aircraft flying at 20,000 ft. altitude. Similar curves for 30,000 ft. altitude show a cross-over point where jet becomes more efficient than propeller at 450 miles per hr.; at 40,000 ft. the cross-over point is 300 miles per hr. It may be concluded that jet propulsion will be favored for high speed, high altitude fighters and bombers. Obviously also there are possibilities for a gas turbine so linked to a propeller that it is used as a complete power plant at low altitudes, and at high altitudes most of the turbo-motor is uncoupled, the kinetic gases then being discharged directly as a jet. One difficulty in this arrangement is to prevent interference between propeller blades and either the

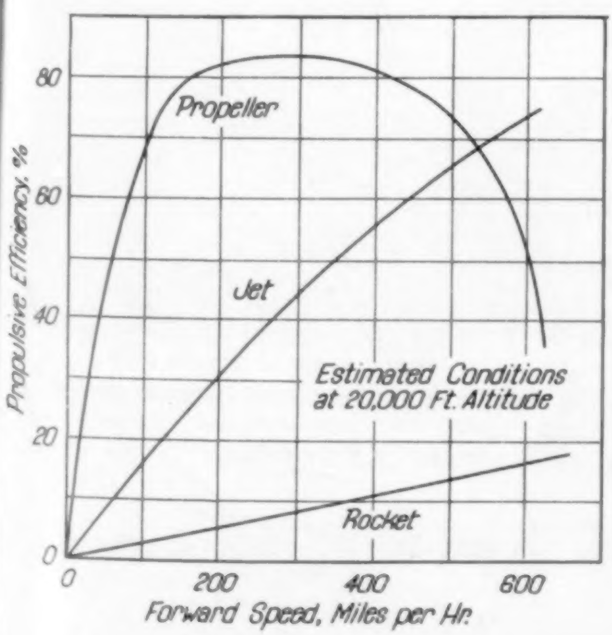


Fig. 10 — Relative Efficiencies at 20,000 Ft. Altitude of Propeller, Jet and Rocket at Various Speeds (From The Engineer)

air inlet or the jet without introducing tortuous air and gas passages and their accompanying frictional losses.

Major problems that had to be solved by Whittle and his collaborators had to do with providing adequate and complete combustion of much fuel in a restricted chamber without destroying the chamber itself, with balancing the amount of turbulance necessary for combustion against the desire for streamlined flow in turbo-motor and jet, and with adjusting the power output. With regard to the latter it should be remembered that the jet is of small mass but of very high velocity, and the velocity is not readily controllable. The jet from an engine-driven propeller, on the other hand, has high mass and relatively low velocity, and the latter is readily controllable by well-known means.

Mention has already been made of the comparatively low fuel economy, at best being but half that of a diesel. At the present time, of course, and in wartime applications, the fuel economy is a very minor consideration in comparison with simplicity, compactness, lightness of weight and almost complete absence of auxiliaries. Accepting at its face value the statement that a compressor-turbine set using its net energy for jet propulsion weighs about half as much as the best aeronautical engine and propeller, one can immediately see that the weight saving in an aircraft requiring, say, 4000 hp. will mean a wholly unexampled increase in pay load (bombs or armament). Likewise the bigger the aircraft the more powerful the engines; there may be some difficulties in making radial or in-line reciprocating engines much larger than the present sizes. Gas turbine enthusiasts, however, envision units generating up to 8000 hp., not needing cooling liquids nor high octane fuel — in fact operating on kerosene.

Analysis of the operating characteristics of the turbo-motor shows that the best (if not the only) chance for a large increase in fuel efficiency is in raising the temperature of the gas entering the turbo-motor. The turbine output varies almost directly with the absolute temperature, and the over-all efficiency of the prime mover may be increased from 16% at gas temperatures of 1025° to 22% at gas temperatures of 1200° F. This illustrates the paramount importance of a metal, greatly improved as to its strength, creep resistance, and scaling resistance, yet a metal that is readily workable and machinable. The problems of thermal expansion are also intensified as temperatures go up, since blades and casings are not at the same degree, yet correct clearances must be maintained for efficient oper-

ation. At the present writing, nothing has as yet passed the censor concerning the nature of these alloys. It is permissible to say that an important American improvement has been made through the work of ⊕ members at Timken Roller Bearing Co. in Canton, Ohio.

While we await the further perfection of high stability alloys, there remains the obvious possibility, in a jet propulsion turbine, of dividing the effluent from the combustion chambers, and cooling only that portion of it that must go through the rotor to a temperature that can be tolerated by its blades.

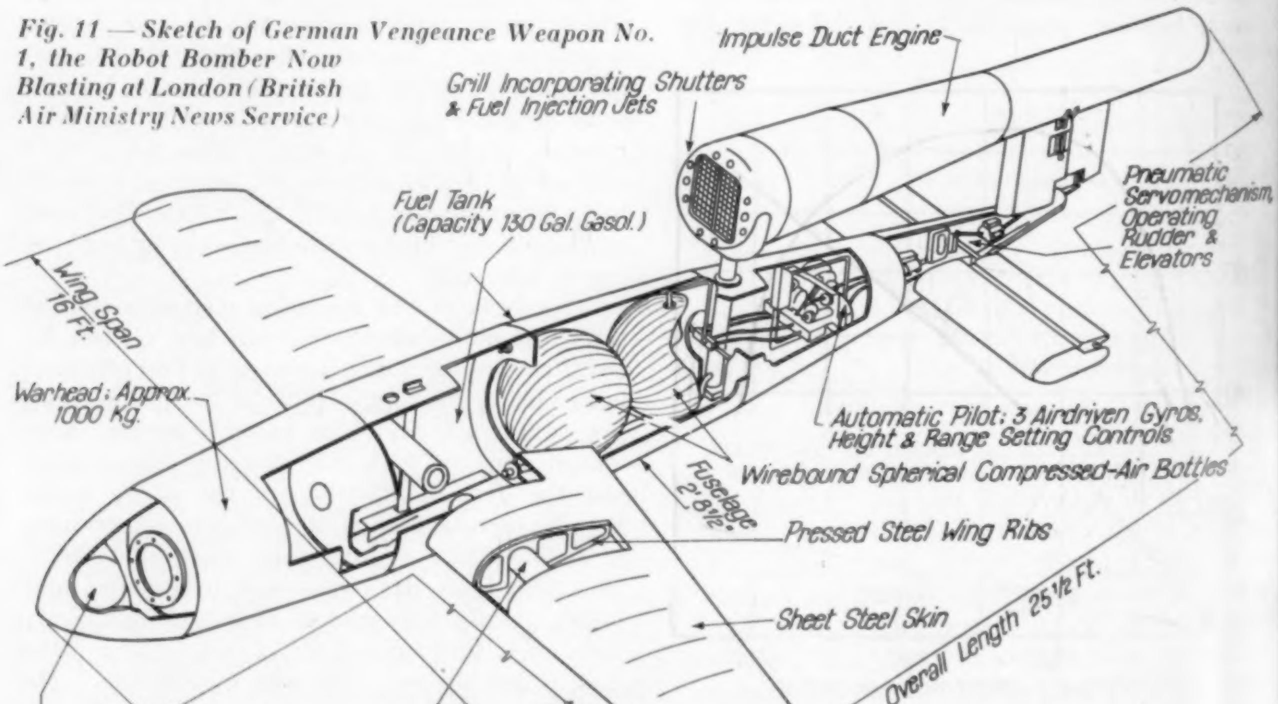
An interesting possibility which has been discussed in German literature is the installation of a jet-nozzle in the tail of a pursuit ship to enable it to get off the ground in a hurry. Such an auxiliary, giving a 1-ton thrust to a 2-ton aircraft would put it up to 20,000 ft. in 1½ min. instead of the 8 min. required to reach ceiling with the regular engine and propeller. Combustion chamber, fuel tank, liquid oxygen cylinders and auxiliaries would weigh about 1000 lb. and this extra weight (unless it could be jettisoned) would hamper the aircraft's maneuvers aloft. This is possibly the reason why the Luftwaffe has apparently not developed the idea. The Russians have either used this scheme, or under-wing rockets made of self-combustible chemicals, to aid in launching heavy aircraft, but these allies of ours are as secretive about military things as our enemies. Chemical-filled rockets, known as *branders,* have also been used by the pre-war Germans to launch gliders. At any rate, as pointed out in the footnote on page 499, such applications would be using the jet propulsion principle in its least efficient ranges.

The Robot Bomber

The British government has released a drawing (from which Fig. 11 is adapted) showing the "pilotless aircraft" now being used by the Germans as their "Vengeance Weapon No. 1". The view was drawn, in all probability, from recovered fragments and espionage reports, rather than after examination of a "dud". These craft are launched from a ramp, possibly with the aid of a take-off rocket; they have a range of about 150 miles at a speed of about 325 miles per hr. Apparently the propulsion system is nothing but a jet of hot gas, the air compressor in the power plants already discussed being replaced by the ram compression effect achieved at high speeds. The compressed air spheres are probably the source of energy for driving the stabilizing gyros and servo-mechanisms. The "buzzing" heard in flight is caused by the fluttering of louvres at the head of the combustion chamber. Operation is apparently an adaptation of ideas contained in Wilhelm Goldau's patents of 1930 and 1932. The

(Continued on page 512)

Fig. 11 — Sketch of German Vengeance Weapon No. 1, the Robot Bomber Now Blasting at London (British Air Ministry News Service)



Personals

Charles G. Purnell, for 38 years with Carnegie-Illinois Steel Corp., the past ten years as specialist in heat treating, has been appointed vice-president, sales, for the Tate-Jones & Co., Inc., Leetsdale, Pa.

D. A. Campbell has left Wheelco Instruments Co. to join the Bryant Heater Co., Cleveland.

William J. Priestley, formerly vice-president in charge of sales development, Electro Metallurgical Co., has been elected president of Electro Metallurgical Co., Electro Metallurgical Co. of Canada, Ltd., Michigan Northern Power Co., and Union Carbide Co. of Canada, Ltd., Units of Union Carbide and Carbon Corp., succeeding the late Francis P. Gormely. E. E. LeVan has been elected president of Haynes Stellite Co., succeeding Mr. Gormely.

Wayne Martin, formerly assistant materials engineer with Sperry Gyroscope Co., Inc., has been appointed sales engineer for the National Smelting Co., Cleveland.

Promoted by Copperweld Steel Co., Warren, Ohio: Robert S. Clingan from Chicago district manager to general manager of sales.

H. Y. Bassett has been appointed acting manager of the Wolverine Tube Division of Calumet and Hecla Consolidated Copper Co., Detroit.

Jesse J. Baum, until recently process engineer and metallurgist with the Allison Engineering Division, General Motors Corp., has joined the Duraloy Co., Scottdale, Pa., as plant superintendent.

Sidney Breitbart, formerly metallurgist at Aberdeen Proving Ground, is now associated with Standard Steel Spring Co., Gear and Axle Division, Madison, Ill., in charge of research and development.

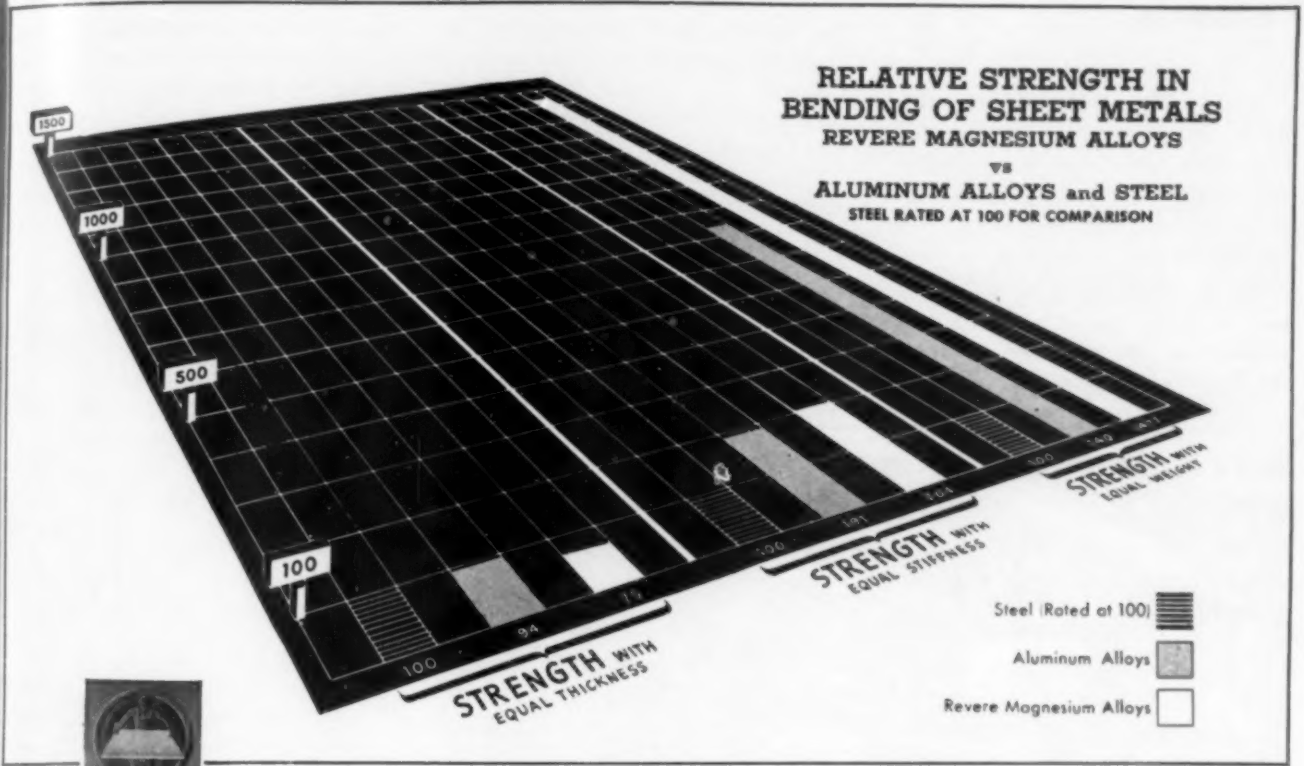
Capt. Milton F. Smith, formerly chief metallurgist, Amplex Division, Chrysler Corp., has been promoted from first lieutenant, and is assigned to Army Air Forces Materiel Command, Chicago.

Sidney A. Pfaff has been appointed Minneapolis-St. Paul representative for the Heppenstall Co. of Pittsburgh.

L. B. Rosseau has been appointed assistant vice-president of the Ajax Electric Co., Inc., Philadelphia.

Eugene M. Smith, formerly operating engineer in the Extrusion Division of Aluminum Co. of America, has been appointed to the staff of Battelle Institute, Columbus, Ohio, for research in non-ferrous metallurgy.

Capt. William F. Silsby, formerly with the Pittsburgh Lectromelt Furnace Corp., has been awarded the Legion of Merit "for exceptionally meritorious conduct in the performance of outstanding service as officer in charge of the Hawaiian Department and Central Pacific Area Searchlight Repair Shop".



Hand-Operated Items. Anything pushed, pulled, lifted, carried. Vacuum cleaners and other household appliances; baby carriages; hand and portable tools; typewriters; instrument cases; luggage; hand trucks and dollies; mailing containers.

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Personals

Walter M. Mitchell ⊕, formerly chief metallurgist for the York Safe and Lock Co.'s special ordnance plant, has been appointed director of research for Mack Trucks, Inc.

W. A. Sherrer ⊕ is now connected with the University of Chicago as an engineer in their metallurgical laboratory.

O. W. McMullan ⊕, formerly in the metallurgical department of Youngstown Sheet & Tube Co., East Chicago, Ind., is now chief metallurgist for Bower Roller Bearing Co., Detroit.

Walter F. Heller ⊕, formerly chief metallurgist of the A. C. Spark Plug Division of General Motors Corp., is now supervisor of research and development for the Nelson Specialty Welding Equipment Corp., San Leandro, Calif.

O. A. Tesche ⊕ has opened his own practice as metallurgical physicist and consultant for engineering metals in Johannesburg, South Africa.

Bernard B. Vaprin ⊕ is now metallurgical engineer in the research and development division of Timken Roller Bearing Co.

Appointed by Allegheny Ludlum Steel Corp. as assistants to Russell M. Allen, vice-president and general manager of sales: W. J. Adamson of Pittsburgh, who will direct magnetic and carbon steel sales; C. B. Boyne ⊕ of Tarentum, Pa., stainless, plurament and alloy steels; P. E. Floyd ⊕ of Pittsburgh, cutting and toolsteels; and Coolidge Sherman ⊕ of Albany, N. Y., warehouse and jobber sales and valve steels.

Robert Taylor ⊕, formerly with United Aircraft Corp., Bendix Aviation (Illinois Division), North American Aviation, Inc. (Dallas Division), and the Industrial Welding and Testing Laboratory of Houston, Tex., has accepted a position as manager of the magnesium foundry at the State College of Washington.

S. G. Eskin ⊕, director of research of the Robertshaw Thermostat Co., Pittsburgh, has assumed the additional duties of director of research and development of Grayson Heat Control, Ltd., Los Angeles.

John A. Atkins ⊕, formerly superintendent of cleaning and finishing department, General Steel Casting Co., is now employed as service engineer for Ordnance Steel Foundry Co., Bettendorf, Iowa.

R. A. Simpson ⊕ has resigned as assistant metallurgist, Wright Aeronautical Corp., Lockland, Ohio, to join the Navy as an ensign, U.S.N.R.

Fred C. Helms, Jr. ⊕ is now vice-president in charge of the New York Office, Latrobe Twist Drill Co.

Elected chairman of the American Coordinating Committee on Corrosion: Frank L. LaQue ⊕ of the development and research division of the International Nickel Co. George H. Young and George W. Seagren, both of Mellon Institute of Industrial Research, were elected vice-chairman and secretary-treasurer respectively.

Jet Propulsion

(Continued from page 504)

impulse duct engine may be sectionalized longitudinally, or be merely one chamber. In any event, when the front louvres are open the air flows through and causes the louvres (inlet air valves) to close. Simultaneously benzene or some highly volatile fuel is sprayed in and ignited. The burning exhaust projects the robot forward, also acts to open the louvres, fresh air scavenges the combustion chamber, and the cycle is ready to repeat. The "engine" may therefore be light in weight, since the pressures developed are low, and it is effectively air cooled. Some auxiliary means would be necessary to start the flying bomb from its launching ways — that is, to accelerate it quickly to a speed where the air stream will be able to act in the desired manner.

The wings and fuselage of the robot bomber V-1 are also simple assemblies of steel stampings and standard shapes, and the gyro system is the most complicated part. It is not radio controlled; once the gyro controls are set and the infernal device is launched, it flies its course until the fuel is used up, deviating only by instrumental errors, variations in drag or manufacturing tolerances on shape, and drift caused by unpredictable air movements. All of these items have considerable effect during a half-hour's flight, with the result that no matter how careful the aim the pattern of hits must look like purposeless blind bombing.

(A recent note in *News-Week* adds that nine varieties of Vengeance Weapon No. 1 have been identified since the start of the bombing on June 15, ranging from the original sketched in Fig. 11, up to a "glider type" with 23-ft. wing span and 30-ft. fuselage. All carry about 1 metric ton of explosives. Some throw in a few incendiaries for good measure.)

Rocket Projectiles

Obviously the robot bomber of Fig. 11 is nothing but a long-range rocket projectile. Its size and complicated steering mechanism are necessary simply because of its long range. At the other end of such limitations is the American "bazooka", a rocket projectile small enough to be juggled with one hand, with a very short range — a matter of a few hundred feet at most — but with tremendous destructive energy. By virtue of its short range the aiming device can be of utmost simplicity — merely a short piece of small "stove pipe" — and its control in flight equally simple (some fins at the tail). Propulsion is true jet propulsion; the "stove pipe" is open at both ends; the rocket moves when the chemicals in the body of the device are ignited and blow back a volume of white hot gas. Speed of the projectile is moderate, far less than a shell from a field gun; its destructive effect is due to the improved explosive in the war head (for example, our "pentolite" is 20% more powerful than TNT) and the discovery that the *time* of detonation has utmost importance — either in the air just above enemy troops, or immediately before contacting the solid body it is intended to demolish. A new rocket (or U.P., "unrotated projectile" as it is technically known) first used on D-day is about as effective as a

(Ends on page 516)

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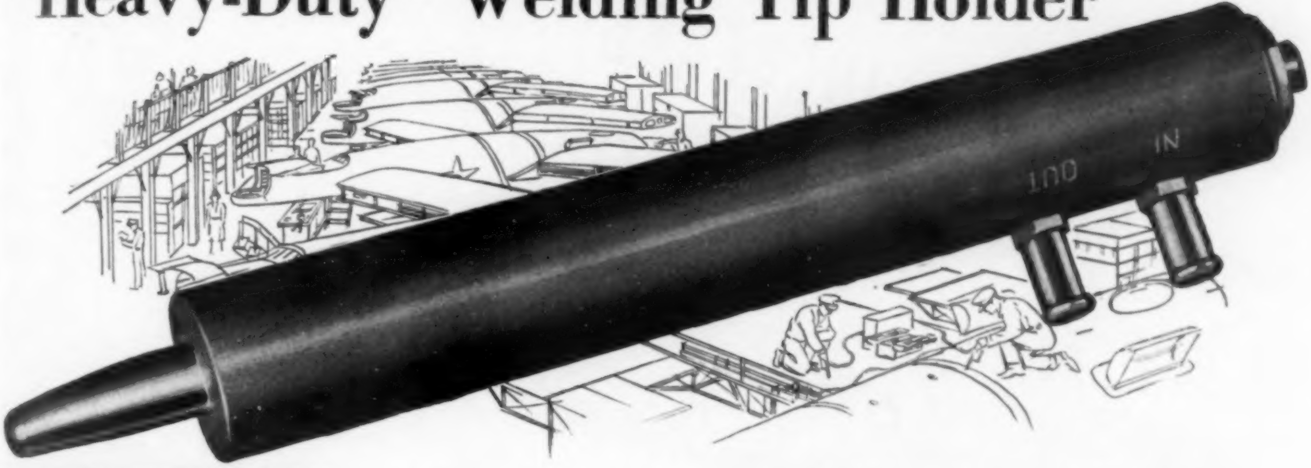
MALLORY

"Heavy-Duty" Welding Tip Holder



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Less Down Time
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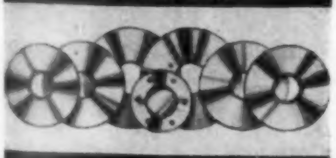
SPOT WELDING TIPS AND HOLDERS

FLASH, BUTT, PROJECTION WELDING DIES



SEAM WELDING ROLLS

Today's increased production calls for resistance welding tip holders that are able to stand up under gruelling service. Mallory answers the need with a product that lives up to its name—the Mallory "Heavy-Duty" Holder.

Carrying an increased flow of water or other coolant, this streamlined, compact tip holder keeps tip temperatures down and increases welding quality and efficiency. Its single piece housing, built to protect vital interior parts, also eliminates coolant leakage troubles.

In addition, the holder features an ingenious knockout device that allows the tip to be ejected quickly by a slight hammer blow at the other end. It has a packing nut, readily accessible at the rear, for quick replacement of packing or adjustments.

The Mallory "Heavy-Duty" Resistance Welding Tip Holder is one of several especially built by Mallory for the tougher jobs of wartime. It has what it takes to stand the gaff.

To get the latest technical information on resistance welding electrodes (for ferrous or non-ferrous metals), write today for your copy of the Mallory Resistance Welding Data Book.

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Buy War Bonds

P. R. MALLORY & CO. Inc.
MALLORY

Standardized Resistance Welding Electrodes

Jet Propulsion

(*Starts on page 497*)

105-mm. shell, but the "gun" weighs about 50 lb.

These factors are revolutionizing fire tactics in short-range fighting. Explosive rockets were actually used by the British army at the siege of Toulon in 1802 and were manufactured at Woolwich Arsenal until 1884. They steadily lost favor with artillerists, however, who were perfecting guns and high velocity projectiles for *long* range. A contrary trend set in during World War I, when trench mortars demonstrated their use, and it became apparent that for *short* ranges a heavy and expensive rifled gun tube and breech mechanism was unnecessary. Hence we find growing use of rocket projectiles by combat aircraft, where the rocket has a high initial velocity and the jet acts with correspondingly improved efficiency.

Slide rails can be arranged under the wings, and so wired that the rockets can be fired either singly or in salvo. Aiming, of course, is done by flying the ship directly at the target. There is no recoil — which is quite an advantage to fast flying aircraft. Accuracy is on the same order as accuracy of fixed-direction machine-gun fire, and rockets have already been given official credit for sinking enemy merchant men and submarines, for silencing anti-aircraft fire on warships, as well as for effective strafing of troops and destruction of gun emplacements and military equipment and works of various kinds on land. The most recent news is that rockets from low flying aircraft stopped the tank battalions that attempted to close the corridor down the Normandy coast through which the Americans streamed on their way to Berlin.

Rockets are also quite useful for protection against aircraft (and robot bombers) and have been so used in England for at least two years. Batteries of twin projectors are so operated that dozens of rockets are exploded in a relatively small volume of space. Automatic pointing and fuse setting enables the whole gun-part to attack a single target simultaneously, and single projectors can be disengaged and aimed by the crew at any target as desired. Beside the simplicity and cheapness of the projector as compared with the AA gun, it can be properly operated by a green crew with much less practice.

EXAMPLE OF *Service* :

A customer writes: "... we have achieved a production rate of 500 L.V.T. amphibian tank axles per day, which is a record in production, considering that these axles are ground to .0006 of an inch tolerance.

We employ 50 people, and this is a rate of 10 axles per day per man. We achieved this record by using Cities Service grinding oil for our grinding operation, Chillo #93 for use in drilling and tapping—and your Sentry #2 as spindle oil."

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ARKANSAS FUEL OIL COMPANY

Blowing Low-Silicon Iron for Steel Castings*

By P. C. Fassotte

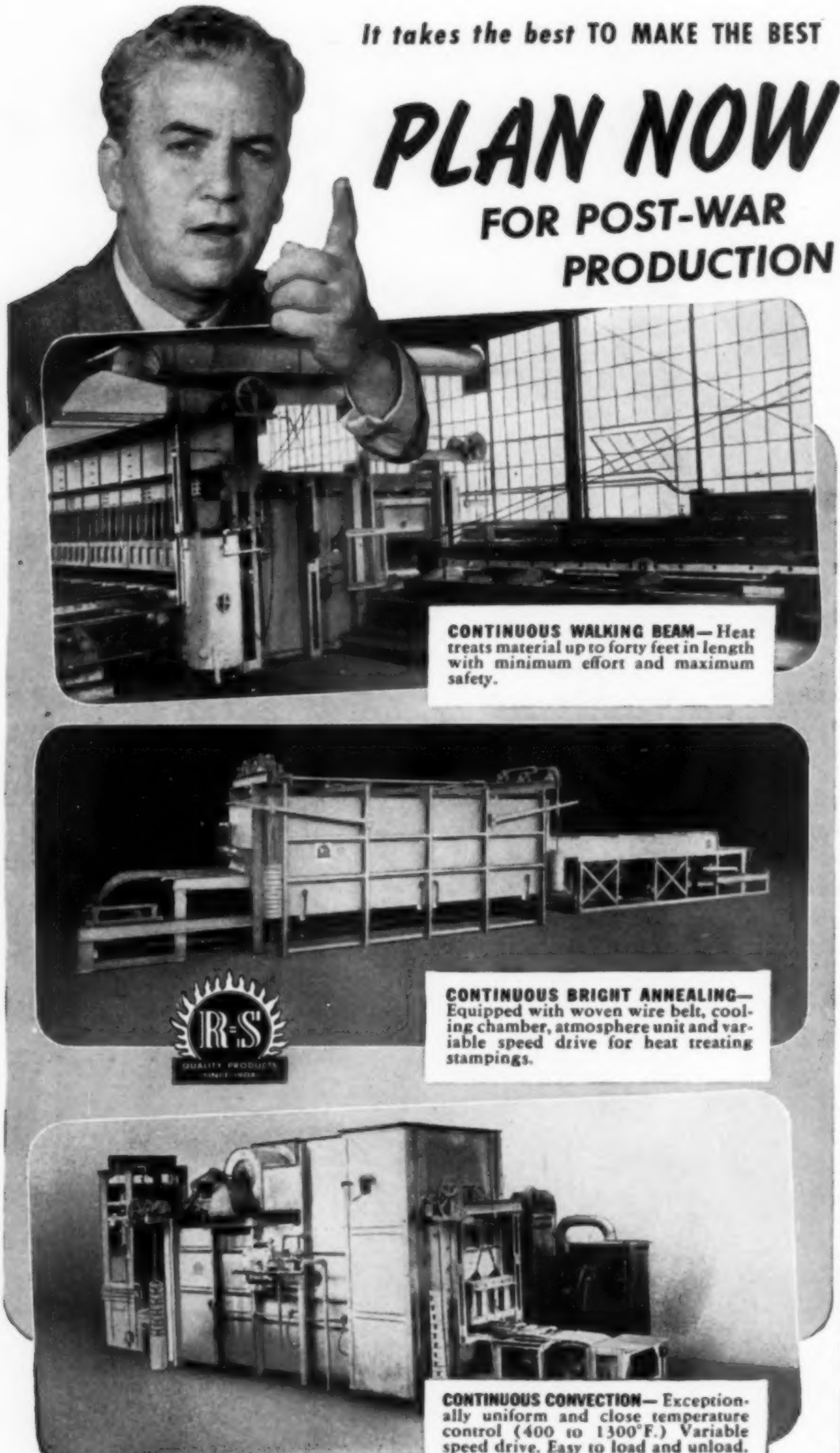
NECESSITY for the manufacture of steel castings from all-scrap charge, without the use of high silicon (hematite) pig or more than incidental amounts of ferrosilicon, led to some experimentation to test operation of side-blown converters. To test the dictum that the molten charge should contain at least 1.3% silicon, a charge containing this amount (together with 3.2% carbon and 0.5% manganese) was blown until the carbon flame appeared and then poured into a ladle and held until it had cooled to 1435° C. (2075° F.). Analysis at that time was 2.7% C, 0.15% Si, 0.14% Mn.

This metal was put back into the converter, the blow finished, poured at 1650° C. (3000° F.), and made acceptable castings. Similarly irons containing only 0.2% Si were melted in an electric furnace, charged into the converter at 1385 and at 1440° C.; both were blown without difficulty and poured 200° C. hotter than charged. It was obvious that the carbon reaction was producing the heat, and consequently was burning to CO_2 rather than (as universally assumed) to CO. Analyses of gas samples taken 4 ft. above the tuyeres generally confirmed that carbon dioxide is overwhelmingly prevalent. Yet under certain working conditions appreciable quantities of CO can be present in the exit gases, and this feature has been observed particularly where blowers are undersized. The function of the silicon reaction now appeared in its true perspective. It is essentially a kindling agent. Its principal purpose in side-blown converter practice is to make up the difference between the temperature of the iron introduced into the converter and the temperature at which carbon reaction starts freely.

Thereupon a converter plant was designed and built wherein scrap charges were melted in four

(Continued on page 520)

*Abstract of "Developments In the Design and Use of Side-blown Converter Plants", advance copy of paper for Iron & Steel Institute, June, 1944.



Blowing Low-Silicon Iron for Steel Castings

(Continued from page 518)

cupolas, the iron (continually flowing) being desulphurized in the ladle with sodium carbonate and transferred in 5-ton lots to one of two rotary furnaces (essentially mixers) of 12 to 25-ton capacity depending on the state of its lining. These furnaces were fired with pulverized anthracite, and heated the iron from 1330° C. ± 50° (2425 ± 90° F.) to a temperature exceeding 1450° C. (2640° F.), where the affinity of carbon for oxygen is pronounced. This iron carries from 0.05 to 0.20% silicon, yet no difficulty is had in producing molten steel sufficiently hot to flow into castings with ¼-in. walls.

Although in principle the converters work with silicon-free iron, in practice small amounts of ferrosilicon are used for minor temperature adjustments. If, for instance, the temperature of the iron is judged to be on the low side, if the converter has been standing for some time before the new charge is introduced or if a particularly high temperature is required in the steel, ferrosilicon additions are made in the converter. For a week's operation the ferrosilicon consumption (75% silicon) represented an average addition of 0.28% of silicon to the converter charges.

A 6 to 1 coke ratio is needed in the cupolas, and the molten iron contains 0.11 to 0.18% sulphur. When desulphurizing with sodium carbonate in the normal manner, the steel frequently showed a sulphur content upwards of 0.06%. When *two* basic-lined ladles were used, merely pouring metal and carbonate slag from the first to the second, the average sulphur content was reduced to 0.027%. Phosphorus in the unselected scrap iron also caused some worry, but fluctuations were averaged out by the mixers to very close to 0.06%. Every day the first few heats tapped from the cupola show a higher phosphorus content than during the remainder of the day. The phenomenon is explained by the phosphorus pick-up from the ash of the initial coke charge (the phosphorus content of the coke being 0.3%).

The rotary mixers were not ready to operate when the plant was started up and for a time steel was made in the normal Tropenas

(Continued on page 522)

Blowing Low-Silicon Iron for Steel Castings

(Continued from page 520)

manner, using a proportion of pig iron and ferrosilicon in the cupola to give iron with upwards of 1% silicon. With these charges the converter blows lasted an average of 18 min. When the rotary mixers were used with irons low in silicon, the average duration of the blow was reduced to 11 min. Slagging is also easier; with low silicon iron there is less slag, it is less viscous and its removal is both easier and faster. To avoid undue scour on the converter lining (no acidic slagging material coming from the iron), silica sand is introduced into the empty converter before the liquid iron, so as to provide the SiO_2 required to balance the iron and manganese oxides. Not only did this addition of sand stop undue corrosion, but it improved the life of the linings remarkably, from an average of 60 heats during normal Tropenas working, to over 200 heats on low silicon iron. This increased life of the linings, however, is partly attributable to the reduced blowing time. It was expected that irons low in silicon and manganese and blown in shorter time would not be subject to the same amount of metallic loss as is encountered in normal side-blown converters. This anticipation was verified in practice. When worked in the Tropenas manner, the blowing loss in the converter was about 9%, which compared favorably with the average metallic loss throughout the country. With low silicon irons and reduced blowing time the metallic loss in the converter, checked as carefully as possible over a number of heats, averages between 5% and 6%.

There are of course some counterbalancing disadvantages to this scheme. Principal among them is the increased capital cost of the plant (mixers, heavy cranes and supporting structures), higher coke and refractory consumption in cupolas, and costs of operating the mixers. In the particular plant under review, the items of increased cost are more than offset by the savings due to cheaper charges, reduced metallic loss and improved performance of converter refractories.

The main purpose of the unconventional design, namely, the conservation of hematite iron, has been fully achieved.

Stud-Welding Systen

By A. M. Candy

A NEW TYPE of deck-constructi
used on a large number
U. S. naval vessels since 1932, a
also on a number of merchant v
sels built by the Maritime Comm
sion, was made possible by a n
method of welding studs and oth
projecting fasteners to a metal su
face. A fully automatic "gun" h
been constructed for this varie
of work, which may be called e
welding. Action is started by
arc-initiating material which sim
taneously furnishes addition
bonding metal and acts as a scav
ger of oxygen, thus insuring hom
geneous and dense metal at t
joint. Studs welded by this metho
when tested, will break through t
body of the stud and not in t
weld. As high as 1200 5/16-in. stu
have been attached by a skille
workman in an 8-hr. shift.

Wood Deck Construction is
follows: The planks are counte
bored with any desired spacing
holes, since the studs can be en
welded anywhere on the platin
without danger of interfering wi
wiring, ventilation ducts, or oth
installation below decks. T
planks are then laid down a
fitted in the usual manner. A sh
wright with a drill scratches t
deck plate sufficiently to remo
paint or oil at each of the sp
where a stud is to be attache
The welding operations are th
performed. The shipwright follo
the welder and places the gromm
washer and special retaining
on the stud, the latter being th
tightened with a forked T-wrenc
Finally a wood plug, previous
dipped in white lead, is press
into the upper part of the ho
closing it tightly, and is then plan
down to present an uninterrupt
smooth surface on deck.

Apparatus — The welding g
is supplied with three adapters
different lengths, three collets a
one dispensing spoon for the a
inducing material. The control c
cuits are completely wired, wi
leads brought out in a three-co
ductor rubber-covered cable, to
connector plug. The gun is al
equipped with a terminal for co

(Continued on page 528)

*Abstracted from *The Weldi Journal*, August 1944, p. 509.

Stud-Welding System

(Continued from page 526)

nection to a source of welding current. The control cabinet is about the size of a small suit case and mounts a main contactor operated by the auxiliary contactor, one current relay, and one timing relay.

Operation — A stud is inserted in the collet and its end adjusted for the correct arc gap between it and the deck plating below, when the tripod feet of the gun, surrounding the collet, are placed firmly on the top of the planking. The gun is then removed and a lava ferrule is properly placed in the bottom of the plank hole. A metered amount of arc-inducing material is located in the bottom of this ferrule.

The gun is then replaced in position with tripod on the flooring. The stud end now touches the arc-inducing material. The trigger switch on under side of gun handle then closes the main contactor, so that welding current flows. The arc-inducing material immediately flashes and produces an arc. After a certain pre-set time interval (about ⅛ sec.) the timing relay closes its contacts which energize a solenoid under the gun handle, and releases a latch that trips a spring and pushes the stud end into the pool of molten metal. The tail piece of the mechanism also opens the interlock switch, which in turn interrupts the welding current and stops operations.

Advantages of this method are: *(a)* It requires a smaller hole in the wood for a given sized stud than any other method utilizing arc welding. *(b)* The insulating lava rock ferrule protects the wood from the heat and, due to an inward flange at the top, keeps droplets of molten metal from splattering the threads. *(c)* The shoulder in the counterbored hole in the wood can give good bearing, with shearing strength of the wood commensurate with the strength of the stud. *(d)* End-welding eliminates the drilling of holes through the metal deck plating and interferences with structures underneath. *(e)* Wood decking can be layed at any time after the steel deck is finished. *(f)* There are no holes in the deck plating to leak. *(g)* The form of special nut permits a deeper wood plug in the upper hole. *(h)* The stud is simpler and more economical than the carriage bolt used in the through construction.

WHAT'S NEW

IN MANUFACTURER'S LITERATURE

METAL WORKING • FABRICATION

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Chambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

Catalog 44 is a new and enlarged reference to Kennametal tools and products. Graphically indexed, this 48-page catalog covers many metal working features. Kennametal, Inc. Bulletin 541.

Practical data sheet describes cutting and grinding compound. Diversey Corp. Bulletin 447.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Complete and valuable study of "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

Safe-T tongs and their use in materials handling are described in new booklet by Heppenstall Co. Bulletin 434.

63-page pocket booklet shows useful tables of weights and measures used in the metal industry. Mesta Machine Co. Bulletin 441.

8-page general catalog outlines the hard facing alloys and overlay metals of this company, with many illustrations and typical applications. Wall-Colmonoy Corp. Bulletin 484.

Attractive 16-page booklet describes the new "MX" grinding tools, citing many features and applications. Carborundum Co. Bulletin 518.

Struthers Wells Corportion's Tangent Bender and its ability to edge bend sheet metal in the lighter gauges is described in illustrated 8-page leaflet. Bulletin 520.

This company has issued two new booklets showing new price lists for sintered carbides. Firth-Sterling Steel Co. Bulletin 486.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

20-page booklet discusses typical problems involved in the selection and application of water-mix oils. D. A. Stuart Oil Co,. Ltd. Bulletin 48

Attractive new bulletin describes the Spencer Turbine Co.'s Sump-Vac a new portable vacuum producer which is said to clean machine sump tanks in 2 to 10 min. Bulletin 49

Pictorial 6-page leaflet describes use of Norton Co.'s resinoid grinding wheels on snagging jobs. Bulletin 550.

Steam drop hammers up to 75,000 pounds are described in booklet offered by Erie Foundry Co. Bulletin 562.

DoAll Zephyr cutting machine and its many advantages for metals and other materials is described in new illustrated literature. Continental Machines, Inc. Bulletin 56

FERROUS METALS

Speed Case and Speed Treat cold finished bars are described in detail in a new profusely illustrated 24-page bulletin issued by the Monarch Steel Co. Bulletin 551.

Use Handy Coupon Below for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 542, 544, 546, 548, 550, 552, 55 556, 558, 560, 562, 564, 566, 568 and 570.

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio September, 194

Send me the Literature I have indicated below.

Name ....Title ....

Company ....Address ....

(Students—please write direct to manufacturers.)

Check or circle the numbers referring to literature described on these 16 pages.

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3	62	107	148	182	240	327	365	411	454	484	511	535	556
4	65	109	149	183	246	328	366	420	455	486	512	536	557
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33	93	134	167	201	305	345	388	441	471	500	526	547	567
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40	96	137	171	204	314	353	398	446	473	502	528	549	
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45	101	142	176	210	322	361	406	449	478	506	531	552	
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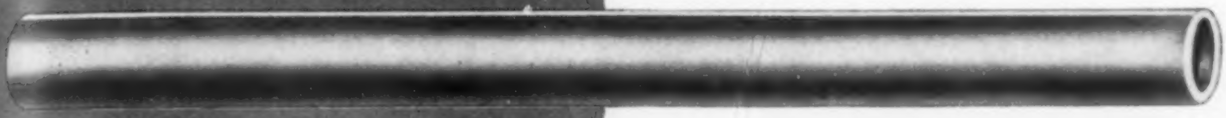
SKF

(SAE 52100)



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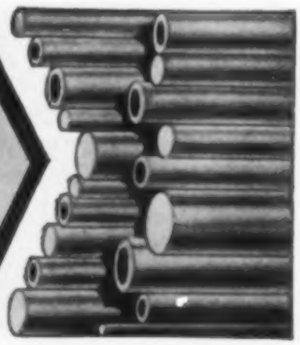

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

Page after page of useful technical data and reference tables on tool steels. Latrobe Electric Steel Co. Bulletin 367.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

New 46-page booklet, "Wear, A Discussion of the Mechanism of Wear Phenomena and Influencing Factors", is said to be the first book in English on the subject of wear. Nitralloy Corp. Bulletin 539.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Chemical analyses, shapes and sizes of Joslyn stainless steel products. Joslyn Mfg. and Supply Co. Bulletin 297.

Tool Steels. Bethlehem Steel Co Bulletin 31.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Attractive new catalog describes the line of steel offered by Peninsular Steel Co. Bulletin 337.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining, long-wearing steel. Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

New booklet gives full information on N-A-X high tensile and N-A-X 9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

Fitzsimons Co. issues interesting leaflet on speed case and speed treat steels. Bulletin 452.

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 540, 544, 546, 548, 550, 552, 554, 556, 558, 560, 562, 564, 566, 568 and 570.

Die of *Speed Treat* Steel Cost Less:

Gave Twice the Production!

CASE STUDY

User: Standard Railway Equipment Mfg. Co.

Application: Corner flanging dies for forming patented Murphy ends and sides for railway cars.

End Use: Dies cold form 3/16" and 1/4" plate on 1,000-ton press. Abrasion is excessive because of scale on plate. Female die is approximately 15" high x 9" wide x 10" deep.

Heat-Treatment: Pack-hardened to 52-54 Rockwell "C" scale.

Result: Dies were formerly made of nickel cast iron and never produced in excess of 100,000 pieces. Dies made from *Speed Treat* open hearth medium carbon hot rolled plate have produced a minimum of 200,000 pieces per die.

Machining costs have been radically reduced with consequent lowering of tool costs. The satin finish on the impression surfaces was produced with far less grinding and polishing.

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

84-page tool and die steel handbo just issued by Ziv Steel & Wire C is a helpful guide to selection, trea ment and use of these importa steels. Bulletin 440.

Kinite alloy tool steel bar stock. B Boker & Co., Inc. Bulletin 258.

Spindle speed calculator is hand chart to figure machining rates o bar steels. Bliss & Laughlin, In Bulletin 333.

64-page booklet describes th welding of stainless steels. All gheny Ludlum Steel Corp. Bullet 384.

32-page booklet which pictorial and textually amounts to a scienti treatise on two carbon steels — Spe Case and Speed Treat — has been i sued by W. J. Holliday & Co. Bull tin 450.

Molybdenum-Tungsten high spe steels marketed under the gener trade name Mo-Max are discusse comprehensively in 52--page book b J. V. Emmons, metallurgist for th Cleveland Twist Drill Co. Bullet 497.

Carpenter Steel Co. offers a co venient four-color chart useful i identifying various types of stainle steels which may have become mixe in stock. Bulletin 507.

Latest data chart, Section D, N 1, shows government "specs" f alloy steels and corresponding co mercial designations. Peter A. Fras & Co., Inc. Bulletin 533.

New 38-page handbook for d signers of stainless steel equipme gives valuable information for acc rately proportioning stronger ligh parts. It is said to be the first ti such detailed values for commerc stainless, both above and below t yield point have been compile American Rolling Mill Co. Bulle 553.

100-page ring-binder catalogs D win & Milner, Inc. tool steels, d scribing selection and applicatio Bulletin 561.

SKF Steels, Inc., has issued a sto list of high carbon-high chro seamless steel tubing and round ba available for immediate delive Bulletin 566.

Important practical heat treati information about stainless ste has just been issued by Rustless Ir and Steel Corp. Bulletin 563.

Use Handy Coupon on Page 54 for Ordering Helpful Literature. Other Manufacturers' Literature List on Pages 540, 542, 546, 548, 550, 552, 55 556, 558, 560, 562, 564, 566, 568 and 57

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

NON-FERROUS METALS

80-page pipe and tube bending handbook has been issued by Copper & Brass Research Assn. Bulletin 399.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

This "Aluminum Imagineering Notebook" presents 12 important economic advantages of aluminum and illustrates numerous examples of things which have been imagineered into aluminum actualities. Aluminum Co. of America. Bulletin 472.

Copper Alloys. American Brass Co. Bulletin 45.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

"Designing with Magnesium" is title of new book offered by American Magnesium Corp. Bulletin 433.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

Printed information on Lithium of interest to nonferrous and physical metallurgists is available from Lithaloys Corp. Bulletin 532.

Two new bulletins present many interesting facts on aluminum tubing and aluminum wire, rod and bar. Reynolds Metals Co. Bulletin 540.

Red-X Aluminum Alloys, produced by the largest single producer of Commercial Aluminum and Magnesium Alloys, the National Smelting Co. are described, applications studied, in this 16-page file folder. Bulletin 499.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

"Some Considerations in Making Test Bars" is the title of an interesting booklet by Federated Metals Div. American Smelting and Refining Co. Bulletin 529.

Facts on Beryllium Copper, including composition, forms available, applications and extensive additional information are presented in this new 16-page booklet by the Riverside Metal Co. Bulletin 511.

WELDING

"Things To Know About Welding Stainless Steel" is title of new booklet that answers many welding questions. The McKay Co. Bulletin 544.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

40-page catalog reviews the progress and many applications of low temperature welding. Eutectic Welding Alloys Co. Bulletin 471.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

Arc welding inspection chart, designed so that operators can tell at a glance whether welds are being properly made, has been issued by the Lincoln Electric Co. Bulletin 411.

Comparable arc welding elecrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Helpful electrode color chart is offered by the Arcos Corp. Bulletin 374.

New Phos-Copper booklet explains ways to braze, design and applications. Westinghouse. Bulletin 455.

32-page booklet presents numerous experience reports from large users of arc welding. General Electric Co. Bulletin 513.

Air Reduction Sales Co. offers 20-page revised price list, "Gas and Electric Welding Supplies and Accessories". Bulletin 512.

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 540, 542, 544, 548, 550, 552, 554, 556, 558, 560, 562, 564, 566, 568 and 570.

WHAT'S NEW

IN MANUFACTURERS' LITERATU

Bulletin No. 14, "How To Repa Broken Cutting Tools With Ea Flo", is filled with practical, instru tional copy, profusely illustrat Handy & Harman. Bulletin 506.

Pocket-sized, slide-type gui showing proper tip sizes, gas pre sures, and other data required fo machine gas-cutting steel is offer by Air Reduction. Bulletin 527.

16-page booklet illustrates th design and construction features certain types of Victor single an two-stage reduction regulators em ployed in the welding industry Victor Equipment Co. Bulletin 5

End-welding with Nelson studs i less than ½ second is described i catalog and price list issued by Ne son Specialty Welding Equipmen Corp. Bulletin 565.

TESTING & INSPECTION

New Burrell Shaker for gener laboratory use is described in ne catalog issued by Burrell Technic Supply Co. Bulletin 543.

Latest technical literature on x-ra and radium protection, together wi lead products catalog, has been is sued by Bar-Ray Products, Inc. Bu letin 463.

The Bristol-Rockwell dilatomete and its use is described in th leaflet by The Bristol Co. Bullet 465.

Metallurgical polishing equipme offered by Precision Scientific Co is described in illustrated bookl Bulletin 359.

Various methods and specific a plications of the measurement of c depth are described in illustrat pamphlet offered by Allen B. DuMo Laboratories, Inc. Bulletin 339.

Bibliography of more than 7 papers dealing with the polar graphic method of metal analysis a a booklet discussing this equipme is offered by E. H. Sargent & C Bulletin 338.

SR-4 strain gage and illustratio of its many uses. Baldwin Sout wark. Bulletin 70.

X-Ray Diffraction Unit. Gener Electric X-ray Corp. Bulletin 72

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Lis on Pages 540, 542, 544, 546, 550, 552, 5 556, 558, 560, 562, 564, 566, 568 and 57

WHAT'S NEW

IN MANUFACTURERS' LITERATU

New book contains wealth of pra tical, usable information on indu trial inspection by x-ray. Westin house Electric & Mfg. Co. Bulletin 7

Universal testing machines an typical uses. Riehle Testing Machin Div., American Machine and Metal Inc. Bulletin 86.

Industrial radiography with ra dium. Canadian Radium & Uraniu Corp. Bulletin 79.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Optical Aids. Bausch & Lomb Op tical Co. Bulletin 94.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adolph I. Buehler. Bulletin 97.

"Radiography of Materials" is title of new 96-page book on industrial radiography. Eastman Kodak Co. Bulletin 331.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin 98.

Attractive, illustrated booklet describes Clark Instrument's precision hardness tester. Bulletin 318.

High intensity industrial illuminator is illustrated and described in new leaflet by Kelley-Koett Mfg. Co. Bulletin 406.

30th Anniversary Catalog shows the special metallurgical equipment offered by Claud S. Gordon Co. Bulletin 410.

Details and various applications of the portable tensile tester are shown in 8-page leaflet by W. C. Dillon & Co., Inc. Bulletin 491.

Advantages and speed of testing with the Magnetic Analysis Corp.'s Comparator are descrbed and pictured in brochure just released. Bulletin 492.

8-page illustrated leaflet describes line of industrial instruments offered by the Brush Development Co. Bulletin 428.

6-page leaflet describes the constant temperature equipment offered by American Instrument Co. Bulletin 493.

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 540, 542, 544, 546, 548, 552, 554, 556, 558, 560, 562, 564, 566, 568 and 570

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New Carbon and Sulphur Determinator is described in this new 8-page leaflet. Harry W. Dietert Co. Bulletin 501.

Many tips and suggestions for industrial laboratories are presented in 24-page March issue of "Curves and References" by Wilkens-Anderson Co. Bulletin 502.

4-page folder on the inspection and control of surface finish is offered by George Scherr Co. Bulletin 508.

New Norelco electronic Searchray Modal 150 is described and several features illustrated in this 4-page leaflet. North American Philips Co., Inc. Bulletin 517.

New 50 KV industrial x-ray unit, its features and applications, are presented in this 8-page leaflet. Picker X-Ray Corp. Bulletin 525.

TEMPERATURE CONTROL

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin 89.

Pyrometer control of high speed salt baths is described in new booklet by Brown Instrument Co. Bulletin 324.

Industrial thermocouples. Arklay S. Richards Co. Bulletin 93.

Operating principle and types available of the synchronous-motor-driven cam program timer are covered in this new 4-page folder. Automatic Temperature Control Co., Inc. Bulletin 487.

36-page thermocouple data book and catalog describes products, prices and presents recommendations for thermocouple users. Wheelco Instruments Co. Bulletin 490.

The Bristol Co. announces a new bulletin B220 describing its new line of Free-Vane Electronic Controllers for temperature, pressure, liquid level and humidity. Bulletin 503.

16-page booklet shows the advantages of Micromax electric control applied to temperature of open hearth roofs. Leeds & Northrup Co. Bulletin 548.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Alnor Pyrocon, the contact pyrometer for surface temperatures, is described in this 6-page leaflet by Illinois Testing Laboratories, Inc. Bulletin 558.

HEATING • HEAT TREATMENT

Attractive 4-page leaflet describes uses, construction features and design of electric car bottom furnaces. Hevi Duty Electric Co. Bulletin 537.

McKee "Walltite Proportioning" and "Entrainment" gas burners are described in new bulletin by Eclipse Fuel Engineering Co. Bulletin 538.

Convection tempering furnaces with temperatures up to 1300 deg. F. are described in this new Hevi Duty Electric Co. Bulletin 542.

"Isothermal Quench Baths Applied to Commercial Practice" is the title of this 12-page paper, a practical and useful discussion of S curves in heat treatment. Ajax Electric Co., Inc. Bulletin 461.

32-page booklet describes 16 interesting industrial uses of high frequency electrical induction. Ohio Crankshaft Co. Bulletin 459.

Quenching oil coolers in heat treating practices are described in this leaflet by the Sims Co. Bulletin 462.

24-page technical data and operating manual covering the Deepfreeze low temperature industrial chilling machines has been issued by Deepfreeze Div., Motor Products Corp. Bulletin 398.

Neutral baths for heat treatment and details of their use are described in this booklet by the A. F. Holden Co. Bulletin 469.

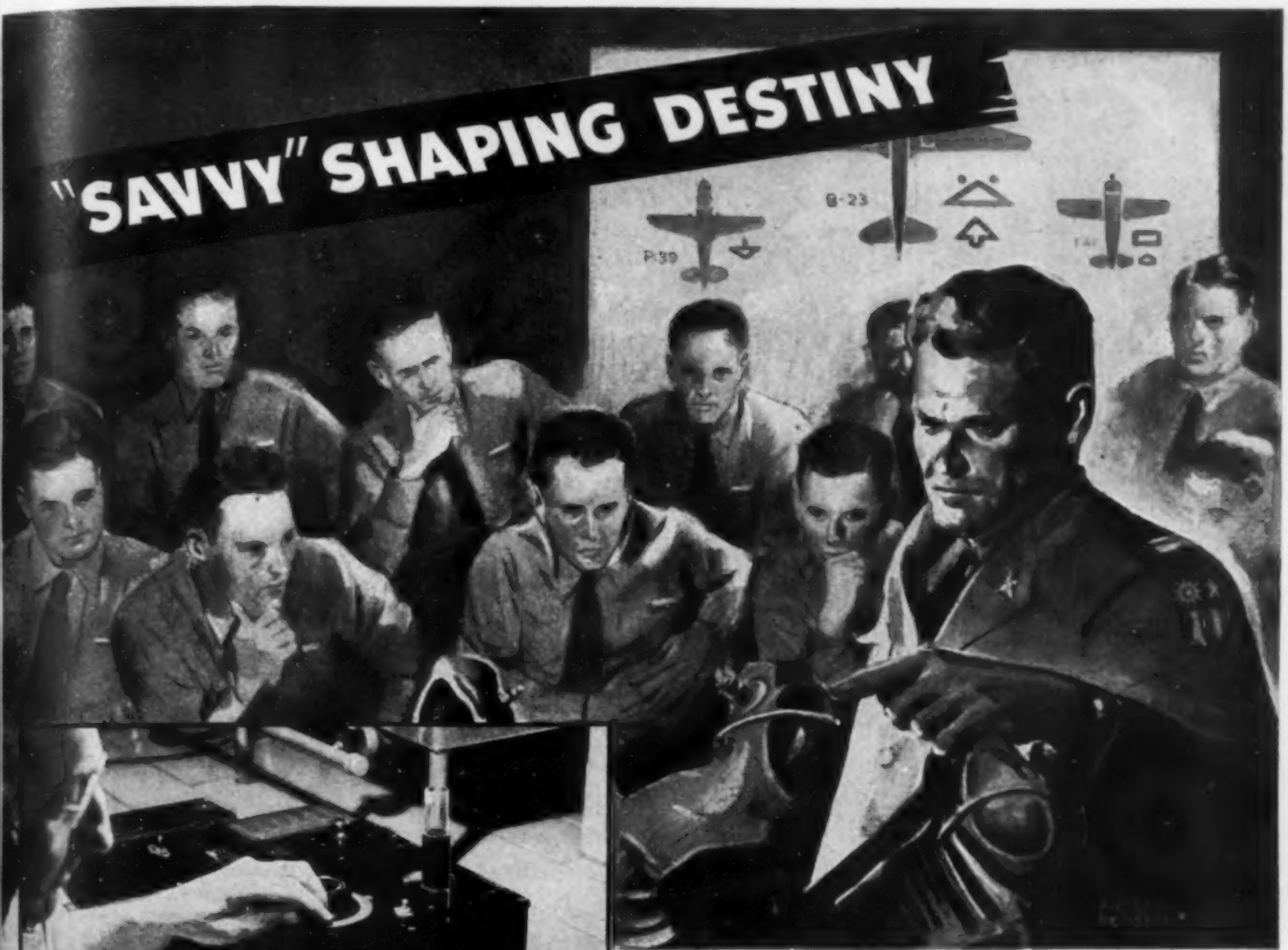
Induction heating. Induction Heating Corp. Bulletin 103.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin 102.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 540, 542, 544, 546, 548, 550, 552, 556, 558, 560, 562, 564, 566, 568 and 570.



Aluminum and Magnesium, Inc. *Sandusky, Ohio*	Samuel Greenfield Co., Inc. *Buffalo 12, New York*
The American Metal Company, Limited *New York City 6*	William F. Jobbins, Inc. *Aurora, Illinois*
Apex Smelting Co. *Chicago 12, Illinois*	R. Lavin & Sons, Inc. *Chicago 23, Illinois*
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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

Furnaces for heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

Gas, oil, and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

Molten Salt Baths. E. I. duPont deNemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin 128.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportioning flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin 139.

Controlled atmosphere furnace. Delaware Tool Steel Corp. Bulletin 141.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Use Handy Coupon on Page 540 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 540, 542, 544, 546, 548, 550, 552, 554, 558, 560, 562, 564, 566, 568 and 570.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

Vertical Furnace. Sentry Co. Bulletin 148.

Furnaces. Tate-Jones Co. Bulletin 142.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

High and low temperature direct fired furnaces. R. S. Products Corp. Bulletin 146.

New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

"The Lectrodryer in the metallurgical industries," a new 4-page bulletin by Pittsburgh Lectrodryer Corp. Bulletin 155.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Turbo-Compressor data book shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

Catalog of heat treating materials. Heatbath Corp. Bulletin 322.

Standardized sizes of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

Use of pulverized coal in the metallurgical industries, equipment and designs, are described by Amsler-Morton Co. in Bulletin 361.

Two new 4-page leaflets describe Surface Combustion's furnaces in the steel wire industry and applied gas chemistry of prepared atmospheres in S. C. Furnaces. Bulletin 547.

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revent Corrosion of Zinc r Cadmium Surfaces

Send for test sample of Iridite-protected zinc or cadmium plating. Let your own laboratory prove how Iridite resists corrosion.

VILL your product—present or postwar—be improved if or cadmium surfaces are rend highly corrosion-resistant? you be even more interested if corrosion-resistant surface does alter the dimensions or texture even the most delicately maed parts? And, finally, will you ome a corrosion-resistant surthat serves as a final finish in dard Army olive-drab and jet k or as an excellent paint base?

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DITE is in wide use on Army and y materiel, both as a final finish and paint base. It meets specifications P-32, 57-O-2C, and other exacting ary and industrial specifications.

IRIDITE as a final finish, does not alter the texture of surfaces. Colors currently available are standard Army olive drab and jet black.

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Write today on your Company letterhead for a test panel of *Iridited* zinc or cad plate; please state which. "Give it the works" with salt spray or other corrosion tests. We are confident that when you have completed the tests, you will make *Iridite* a "must" for your product. For your test sample and further information about *Iridite*, write, wire or phone: Rheem Research Products Incorporated, 409 Chemical Building, 2523 Pennsylvania Avenue, Baltimore 17, Maryland.

TEST THIS SAMPLE of zinc or cadmium-plated steel, half of which has been treated with *Iridite*. Put the entire panel to any corrosion test you choose, then compare the two halves. You'll see at once why *Iridite* meets Army-Navy Aeronautical Specifications AN-P-32, Army Ordnance Specification 57-O-2C for Type I finish, and the exacting specifications of many large manufacturers.

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Grand Rapids Distributor: J. C. Miller, Grand Rapids 4, Michigan.
Detroit Distributor: Wagner Brothers, Detroit 2, Michigan.

WHAT'S NEW

IN MANUFACTURERS' LITERATU

Line of Altitude Chambers which products and materials m be tested at any given altitude, te perature and degree of humidity described in new catalog issued Kold-Hold Mfg. Co. Bulletin 549.

W. S. Rockwell Company h issued two new bulletins—an 8-pa leaflet on oil or gas fired forge fu naces and a 4-page folder on stan ard pot furnaces. Bulletin 555.

"Why Heat Treat in Baths?" is t title of an interesting discussion the Bellis Heat Treating Co. on t use of liquid heating media and t latest Edicurrent Furnaces. Bul tin 560.

Rapid oil coolers and heat transf equipment are described in new ca log issued by Bell & Gossett C Bulletin 365.

Laboratory and tool room furna Mahr Mfg. Co. in new Bulletin 327.

82-page catalog describes in det General Electric heat treat furnac Bulletin 380.

Furnaces for heat treating too dies and parts are described in ne leaflet by Despatch Oven Co. B letin 362.

New booklet describes unifor case hardening up to .150" with co trolled carburizing baths. Americ Cyanamid & Chemical Corp. B letin 372.

New book "Hardness" describ and evaluates hardness research noted pioneers, methods of testi and testing instruments. Nitrall Corp. Bulletin 366.

Four basic heat treating atm pheres are described in new book by Westinghouse. Bulletin 383.

The complete line of heat treati furnaces, burners and other equ ment of this company is describ and illustrated in new bulletin just issued. Eclipse Fuel Engine ing Co. Bulletin 483.

Vapocarb-Hump method for h treatment of steel is the title of newly-revised catalog issued Leeds & Northrup. Bulletin 453.

"Heat Treating Topics" is title new bulletin of special interest heat treaters, issued by Rex & E Bulletin 424.

Thirty-two-page booklet, "Produ tion Data," presents several artic from "The Houghton Line." E Houghton & Co. Bulletin 475.

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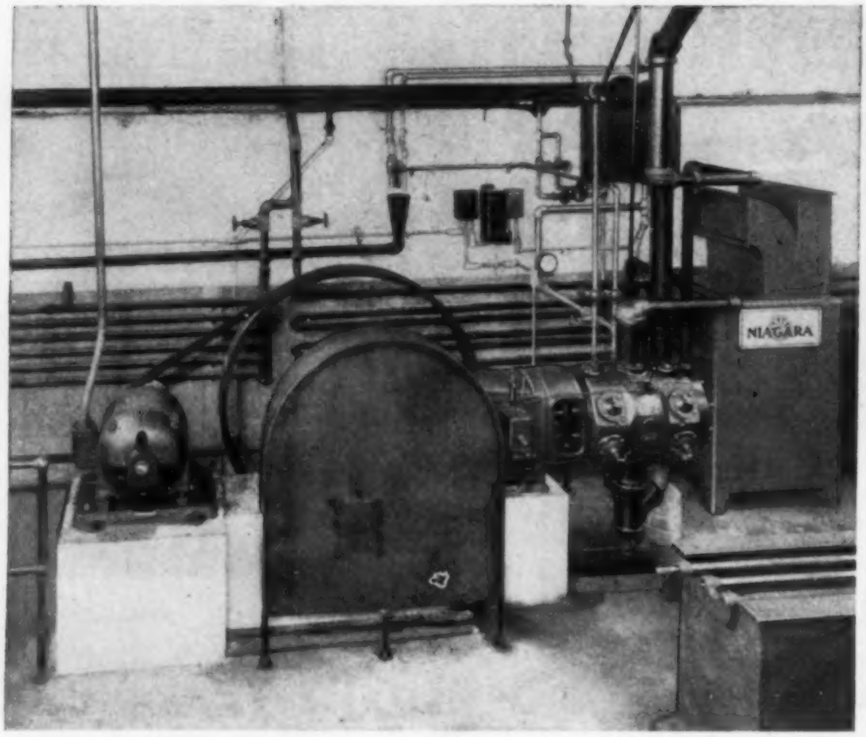

WHAT'S NEW

IN MANUFACTURERS' LITERATUR

112 pages packed solid with dow to-earth data on industrial combu tion and heat practice. Hauck Mfg Co. Bulletin 477.

A new technical bulletin give information on Calliflex Bi-metal Callite Tungsten Corp. Bulletin 47

Aero Heat Exchangers for the con stant and accurate control of temper ature in liquids or gases are de scribed in this 4-page leaflet b Niagara Blower Co. Bulletin 516.

Interesting 20-page booklet con tains extensive heat treating infor mation, including a glossary of term table of weights of square and roun bars and a hardness conversion table. Pittsburgh Commercial Hea Treating Co. Bulletin 509.

Gas-fired tool room furnaces an pot furnaces are described in thes two booklets by Bellevue Industri Furnace Co. Bulletin 522.

Merits and economy of pulverized coal firing for metallurgical furnace are discussed in this bulletin by Bab cock & Wilcox Co. Bulletin 530.

REFRACTORIES & INSULATION

Several basic refractories for th open hearth and electric furnace are described in this 8-page leafle by Basic Refractories, Inc. Bulleti 559.

Conductivity and heat transfe charts. Johns-Manville. Bulletin 16

Wesgo super refractory shapes a described in this bulletin. Wit ability to withstand almost an amount of thermal abuse, the shapes possess high fusing range (u to 3100 deg. F.), low thermal co ductivity and complete freedo from impurities such as iron. West ern Gold and Platinum Works. Bu letin 526.

Zircon refractories in aluminu open hearth furnaces. Chas. Taylo Sons Co. Bulletin 347.

Steel Plant Cement for hot or col patching of soaking pits, ope hearths, electric furnaces, forgin furnaces and reheating furnaces i described in new folder by Electr Refractories & Alloys Corp. Bulleti 407.

Use Handy Coupon on Page 540 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 540, 542, 544, 546, 548, 550, 55 554, 556, 558, 560, 564, 566, 568 and 57

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Electric-furnace graphite molds and sintering boats and carbon heat treating boxes are described in Catalog Section M-8000. National Carbon Co. Bulletin 545.

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Heavy Duty Refractories. Norton Co. Bulletin 164.

"Carbofrax" refractory skid rails are described and blueprinted for many types of furnaces in this 20-page booklet by the Carborundum Co. Bulletin 500.

D-E insulating materials and the application are described in ne data booklet by Armstrong Cork C Bulletin 208.

FINISHING • PLATING • CLEANING

A protective, deep black finish steel. Heatbath Corp. Bulletin 17

Roto-Finish equipment for d burring, buffing, polishing and colo ing. Sturgis Products Co. Bullet 170.

Motor-Generators for electropl ing and other electrolytic processe Columbia Electric Mfg. Co. Bullet 173.

Alvey Ferguson Co. shows ho various product washing problem were solved. Bulletin 172.

Electrochemical Descaling. Bu lard-Dunn Process Div., Bullard C Bulletin 212.

Airless Rotoblast. Pangborn Corp Bulletin 176.

Rust inhibiting wax coatings fo protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin 17

Tumbling and cleaning. Glob Stamping and Machine Co. Bulleti 179.

Catalog on finishing and cleanin Frederick Gumm Chemical Co., Inc Bulletin 292.

"Indium and Indium Plating". In dium Corp. of America. Bulletin 18

Jetal process and its characteris tics as a protective coating. Alros Chemical Co. Bulletin 213.

Cyanide zinc and bright zinc plat ing with Turco Type X, Turco Por kleen and Turco Penetrol is describe in this 10-page booklet by Turc Products, Inc. Bulletin 495.

Lead plating is discussed in ne booklet issued by Harshaw Chemica Co. Bulletin 109.

Service report describes use Oakite machining, drawing, degrea ing and descaling materials. Oaki Products, Inc. Bulletin 210.

Special data sheets on compound for various cleaning jobs are offere by MacDermid, Inc. Bulletin 436.

Technical bulletin describes ma terials developed to meet special ized processing and cleaning need Kelite Products, Inc. Bulletin 438.

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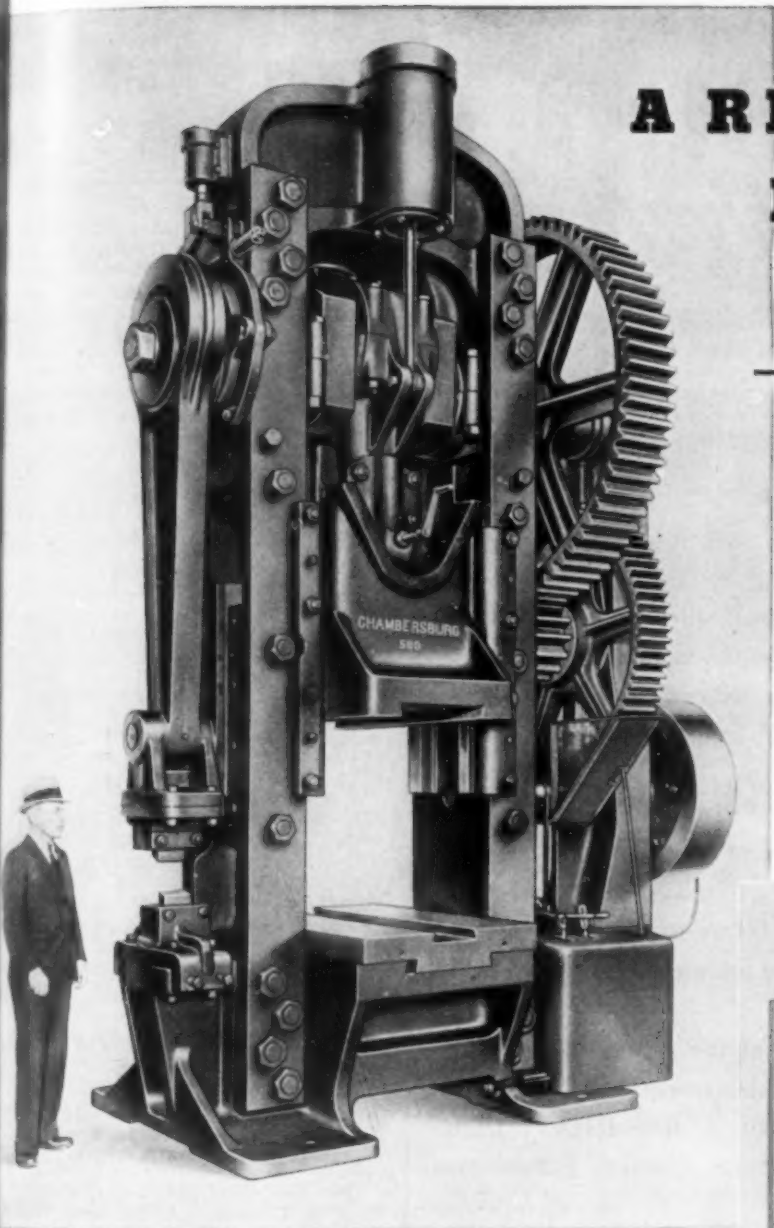

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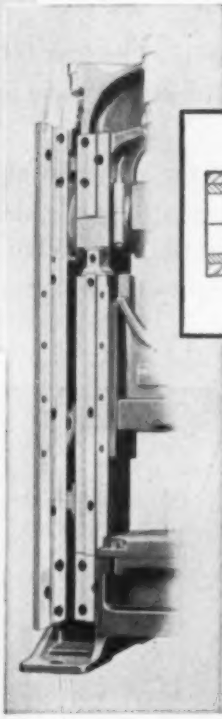
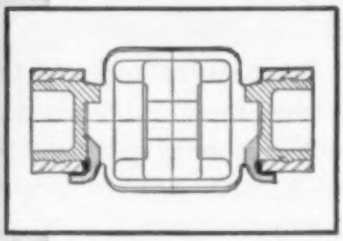


Detail of Interlocking Side Frame Construction



INTERLOCKING FORGED STEEL SIDE CONSTRUCTION

(PATENTED)

Surprising strength and rigidity is attained by the side frame construction. The tongue-and-groove construction binds base, forged steel uprights and yoke into a rigid unit. Compare with non-rigid construction in other presses.

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WHAT'S NEW
IN MANUFACTURERS' LITERATU

"Deoxidine" for a better rust re- moving and metal cleaning job is de- scribed along with several applica- tions in this 4-page leaflet. Ameri- can Chemical Paint Co. Bulletin 5

Three new booklets have been is- sued by the Enthone Co. describing an acid addition agent, hard drying rust-inhibiting waxes and a new al- kali steel cleaner. Bulletin 420.

Several practical data sheets show cleaning methods used on aluminum, brass and steel. Diversey Corp. Bulletin 446.

New 144-page catalog "Chemicals by Glyco" features many tables of useful chemical and physical data. Glyco Products Co., Inc. Bulletin 449.

"Surface-Peening" by shot-blasting to improve the strength of metal parts is described in this leaflet by W. W. Sly Mfg. Co. Bulletin 521.

Two informative cleaning booklets have been issued by Detrex Corpora- tion. 16-page booklet emphasizes fundamental practices for economi- cal use of degreasing solvents in metal cleaning departments. 8-page booklet describes alkali and emul- sion cleaning compounds for all types of metal cleaning jobs. Bulle- tin 554.

ENGINEERING • APPLICA- TIONS • PARTS

Heat treating fixtures for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.

Pressed steel pots are described by Bell & Gossett Co. in new Bulletin 364.

Specifications and physical prop- erties of bronze and aluminum alloys are shown in Olds Alloys Co. Bulle- tin 457.

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bul- letin 190.

24-page catalog is guide to proper- ties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 31

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

16-page booklet gives engineering standards and technical information on "AERO-THREAD" screw thread system. Well-illustrated and helpful booklet by Aircraft Screw Products Co., Inc. Bulletin 567.

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 540, 542, 544, 546, 548, 550, 552, 554, 556, 558, 560, 562, 564, 568 and 570.

WHAT'S NEW

IN MANUFACTURERS' LITERATU

Catalog gives complete specifica tion data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

New 32-page illustrated bookl contains much data on mangane steel for the railroad industry American Manganese Steel Div. Bulletin 388.

Illustrated leaflet presents data and uses of special alloys resisting cor rosion, high temperatures and abra sion. The Duraloy Co. Bulletin 39

New information sheets on tapere and formed tubes have just been issued by Summerill Tubing Co. Bulletin 369.

54-page booklet, "File 41—Eng neering Data Sheets", gives complete facts on Ampco Metal's physica properties and service record. Bulletin 368.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics issued by Drop Forging Assn. Bulletin 240.

Details of new Chemicast process for small brass parts will be supplied by Chemicast Div., Whip-Mix Corp. Bulletin 330.

Electrical, corrosion and heat re sisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

Reference data book entitled "The Improvement of Metals by Forging" has been issued by Steel Improve ment & Forge Co. Bulletin 409.

Interesting and informative litera ture on "Pomet" powder metallurg products. Powder Metallurgy Corp. Bulletin 454.

Industrial applications of Nation al and Karbate carbon and graphite products are illustrated in 16-page booklet issued by National Carbon Co., Inc. Bulletin 426.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin 197.

Steel Castings. Chicago Steel Foun dry Co. Bulletin 199.

Heat Resisting Alloys. General Al loys Co. Bulletin 200.

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 540, 542, 544, 546, 548, 550, 552, 554, 556, 558, 560, 562, 564, 566 and 570

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Handsome 12-page brochure pictures the cast steel breech rings and their advantages as produced by the Ohio Steel Foundry Co. Bulletin 515.

"Mechanical Springs, Their Engineering and Design" is the title of a 106-page handbook just issued jointly by the divisions of Associated Spring Corporation. Bulletin 481.

Many types of heat treating and pickling baskets and containers are shown in new booklet by the Stanwood Corp. Bulletin 445.

Complete line of Mallory radio, electrical and electronic parts, with sizes, dimensions and rated capacities is described in new 36-page booklet. P. R. Mallory & Co., Inc. Bulletin 448.

The Wilco Blue Book deals with the 29 Wilco Thermometals, their properties, functions, applications and temperature ranges. H. A. Wilson Co. Bulletin 531.

Illustrated leaflet describes stainless steel castings by Atlas Foundry Co. Bulletin 437.

Illustrating several heat resistant alloy applications, this 4-page leaflet cites four factors essential to efficient alloy use. Sterling Alloys, Inc. Bulletin 504.

Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin 206.

Three-color chart of decimal equivalents. John Hassall, Inc. Bulletin 458.

Drop, hammer and upset forgings. Kropp Forge Co. Bulletin 534.

Steel Forgings. Transue and Williams Steel Forging Co. Bulletin 535.

Specifications and diagrams are included in description of welded rings and bands. American Welding & Mfg. Co. Bulletin 536.

Heat and corrosion resistant castings as engineered by Alloy Casting Company are described along with plant facilities in an interesting 20-page booklet. Bulletin 557.

MELTING • CASTING • MILL OPERATIONS

Ingot Production. Gathmann Engineering Co. Bulletin 185.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin 189.

8-page illustrated booklet describes crucible melting furnaces for brass, bronze, aluminum, copper and other alloys. Stroman Furnace & Engineering Co. Bulletin 473.

Crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin 183.

This ring-binder presents 24 pages on the use and effect of Titanium in steel and cast irons. Titanium Alloy Mfg. Co. Bulletin 470.

52-page booklet describes Moore rapid Lectromelt furnaces for iron, steel, nickel and copper melting and refining. Pittsburgh Lectromelt Furnace Corp. Bulletin 404.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin 186.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin 137.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin 215.

"Fisher Magnesium Scrapbook". Fisher Furnace Co. Bulletin 281.

Attractive booklet describes growth, facilities and offers valuable alloy hints. Niagara Falls Smelting & Refining Corp. Bulletin 246.

Interesting, descriptive leaflet on metal reclaiming mill offered by Dreisbach Engineering Corp. Bulletin 284.

4-page leaflet describes an improved line of Despatch Oven Co.'s Coremaster Drawer Type Ovens. Advantages of this type of oven for the large and small foundry and list of 48 standard models available are presented. Bulletin 556.

GENERAL

New leaflet describes interoffice communication system offered by Executone Communication Systems. Bulletin 385.

Use Handy Coupon on Page 540 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 540, 542, 544, 546, 548, 550, 552, 554, 556, 558, 560, 562, 564, 566 and 568.